OUR OWN WEATHER

EDWIN C. MARTIN

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FAIR-WEATHER CLOUDS

Their heaped-up aspect has given these clouds the name of cumulus. They are known also as wool-pack clouds. They form in fair weather, in the middle of the day, when the air, warmed near the earth, rises in gentle currents and cools and condenses. Their particular mark is rounded, or domelike, tops and fairly straight bases. At their bases they are ordinarily from three-quarters of a mile to a mile from the ground.

OUR OWN WEATHER

A SIMPLE ACCOUNT OF ITS CURIOUS FORMS, ITS WIDE TRAVELS, AND ITS NOTABLE EFFECTS

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I

A WORD IN COMMENDATION OF OUR WEATHER

THE weather itself is but an activity. The air of the atmosphere, like the water of the sea, and, indeed, like all nature, including man, is forever seeking ease and never quite finding it. The weather is simply the air's *business*—its runnings to and fro, its conflicts and avoidances, its unions and divisions and graspings and givings-up in pursuit of this one aim which it never fully achieves. If expanses of atmosphere were as open to view as expanses of sea the slightest brushes of weather would be all the time giving us intimation of a vastness, a puissance, and a mystery far exceeding the sea's.

Our never failing to find attraction in the sea has led us to speak of it as having a spell. One

might seem to be pressing the matter pretty far to claim for the atmosphere, considered by itself, that it had a spell. But certainly in the weather, the all-pervasive product of the atmosphere and almost the only thing by which the atmosphere is known to us, one may without extravagance claim to find a spell. It is a spell all the stronger, all the more enticing, because of the meager visibility of the matter in which it lies.

I sit before an open window that frames in for me the top of a handsome tree. Whenever I lift my eyes I catch a little spur and refreshment from the flutter and sway revealed to me in clusters of leaves and branchlets. Most times, in any thought I may chance to give to it, I confine the movement wholly to the tree. If I definitely ally it with the tree it gains appreciably in pleasantness and interest. But if I go farther, as I may, and ally the movement as definitely with the other factor in it—the breeze—I am soon on a pursuit that may easily become a perfect fascination. The tree itself is not without fascination. Its beauty of color and of form, its aspect of rightness and sufficiency, the sense of its great, sure growth in such quietness and out of sources largely

obscure, combine to produce in one a feeling of weirdness and enchantment. Nothing could be more natural than for the old fairy-tale-tellers to shut their enchanted human beings up in the trunks of trees. Sit for a little while looking intently at a great tree and you will feel just such a fate coming fell upon yourself.

But no tree can work the wonders for you, send through you the rills of undefined delight, give you the far-off glimpses and visions that the breeze can if you lend it your full fancy. And yet the breeze is weather in one of the lightest of its exertions. Half the spell of the sea itself is after all only the spell of the weather. Take from the sea all that the weather imparts to it in the way of movement and color, and it would be a pretty dull, tame affair. Indeed, without the weather all nature, all life, if life there still were, would be a dull, tame affair.

The weather ought not to fail of interest in any country on the globe. But there are good reasons why our own weather should, at least to ourselves, particularly abound in it. Ours is, to begin with, a weather of great variety. We complain of this sometimes when two kinds succeed each other with a certain brusqueness. But it is not a genuine grievance with us. Let

autumn loiter on into the middle of winter, or winter blot out spring and then break abruptly off into full summer, and the complaints we make are those of people who feel that a radical injustice has been done them.

We are not simple in either our nature or our habits. We should not be content to live under the trees in continuous warmth or in ice huts under continuous cold. We demand, indeed, at least four good, well-marked seasons and a fairly active exchange month by month, and even day by day, between fair weather and foul. How far in this, as in so many other matters, our luxuriousness has arisen from the mere possession of luxury rather than from something quite special and fine in our own prime creation, it would be hard to say. But the luxuriousness itself is indisputable; and the weather, on the whole, meets our sumptuous exactions with generosity.

While abundant in variety, our weather is not, however, in this pre-eminent. The weather of some other countries has as much or perhaps even more. Nor does ours, as a whole, enjoy a clear superiority to the weather of all other countries in either one of the two primary qualities of weather, temperature and moisture.

It is neither the hottest nor the coldest nor the wettest nor the dryest weather in the world. The United States do hold, though, at the present time, I believe, the world's record for the highest absolute heat. At Mammoth Tank, California, in the Colorado Desert, on August 17, 1885, a temperature of 130 degrees in the shade was recorded. This record was repeated at Volcano, in the same locality, in June, 1896.

Neither of these is a Weather Bureau record, and they may require a little discount for that reason. But a record of 128 degrees made in the same month and year as that at Volcano, but at another place in the same region—Salton—has the Weather Bureau's indorsement. A record of 127.4 degrees in Algeria, on the northern edge of the Desert of Sahara, is commonly named as the highest yet made in any other quarter of the world. The region, though, in which with us anything like these high records ever becomes possible is very small—one little corner of Arizona and one little corner of California—and offers in its own weather no real sample of that of the country at large.

We have also some noteworthy records of absolute cold. The lowest are 63.1 degrees below zero at Poplar River, Montana, in Janu-

ary, 1885, and 65 degrees below zero at Fort Keogh, Montana, in January, 1888. But these, like the highest records of absolute heat, are merely local. Even the one state in which they both occur is not truly represented in them. It is not our coldest section. Northern Minnesota is the region of lowest mean temperature in the United States; and the lowest temperature on record there is 59 degrees below zero at Leech Lake Dam, February 29, 1889. Even at 65 degrees below zero, though, we are not very near the world's record in low temperatures. Siberia holds that with apparently entire security. A temperature has been recorded there of 90.4 degrees below zero, and it is in its general temperature the coldest part of the earth—colder even than the region around the poles.

The same two little corners of Arizona and California that have won us the world's record for absolute heat have won it also in the matter of aridity. They have the smallest recorded rainfall of any places on earth. But this is almost as pronouncedly only their own little affair as is their unequaled warmth. There is, indeed, in the United States a large region of scant rainfall—that extending from the northern

to the southern boundary of the country and from the Sierra Nevada and Cascade Mountains on the west to a line beginning in the eastern part of North Dakota and running almost directly south down to and through the middle of Texas. But owing to the fact that the bulk of the fall is just at the time when rain will be of most service, a large part of the region is, as we know, very productive. East of this, over all the country to the Atlantic Ocean, the ordinary rainfall is such that scarcely in all the world is there to be found another such extent of territory so amply and yet so moderately and so evenly rained upon. Of excessive rainfall the country supplies at no point records of the premium order. Eccentric annual falls of something over one hundred and forty inches are talked about; but they cut no figure beside, for instance, the records of nearly five hundred inches of annual fall that are reported from India.

A country covering more than three million square miles and of such diversity as ours could not fail to offer specimens of about all the kinds of weather that ever befall. Records like those just recited show that the United States do this with quite the expected amplitude. But the

point of truly great note and interest is that, notwithstanding many and often the extremest diversities, we still have a weather that we can properly call our own, a weather peculiar to the country and common to the whole of it. Of not less note and interest, though, is the fact that this weather has a comparatively simple and perfectly determinable character. It does not blot out the seasons: in every part of the country we have, more or less well marked, a winter, a spring, a summer, and an autumn. It does not extinguish the differences between northern and southern latitudes: Texas, for example, will always show year by year as on an average some twenty-five degrees warmer than Maine. It does not remove the contrasts between night and day or those of susceptibility between varied local exposures. Day breeds warmth, night coolness, a greater warmth is acquired under some exposures than under others. What the weather does do is to maintain clearly its own character even in the face of such diversions and differences.

Knowing of it, however, no more than just this, one might get the impression of it as of a sort of formless, impalpable something, spread out somewhere above us over the whole country

and lying there in a perennial and obstructive sluggishness—a thing that merely kept the natural and proper weather more or less from its work. But that is exactly what our weather is not. Sluggishness is its last characteristic, and staying on is not at all its habit. It has its intervals of relaxation or partial repose; like some other activities, it shows less energy in summer than in winter. But, regarded the whole year through, it is practically always in progress.

It has, too, as definite an organization and is as full of its own vitality as any living creature. It presents itself in two forms, sharply contrasted but intimately interdependent. In one or the other of these it appears always in some far western part of the country—often on the Pacific coast, but oftener in the northern Rocky Mountain region—and, by paths that have come to be well marked, crosses to the Atlantic coast. In every small locality to which it comes it suffers modifications, and these modifications are often of the greatest importance to the locality in which they occur. But whatever reception different localities accord it, whether hospitable or hostile, whether they add to it or take from it, and whatever they do to it or it

does to them, they rarely alter it in its essential form, and it passes on from one to another and finally out of the country and off over the Atlantic Ocean with as clear a character and identity as it had when it first appeared. The same two forms are shown in the weather of other regions in the temperate zones. But nowhere else do they have the great extension, the long length of clear, unbroken course, and the strong persistence that they have in the United States. And this it is that gives special distinction to our weather and makes it truly a national weather and truly ours.

But, while our weather is national, it is the weather of a nation of the first class and of a people highly civilized. Though national, it is not provincial. Like our political institutions and administration and our commerce, it has its world connections, and it would hardly be quite worthy of us if it did not have them. To apprehend it in its real peculiarities and in the full magnitude of its manifestations requires some attention also to the weather at large.

II

THE WEATHER AT LARGE

OF all weather, through however long a genealogy, the first father is, of course, the sun. That great molten body, more than three hundred thousand times as large as the earth, is always giving off on all sides into space a something of which we hide what remains as yet a nearly complete ignorance by calling it solar radiance, or solar energy, or simply sunshine. The earth, lying in line, is constantly smitten by some few shreds of this vast outgiving—a two-billion-two-hundred-millionth part, to be devoutly exact. This seems a trifling amount; but it would suffice, if all diverted for the moment into such needless tasks, to boil quantities of water or lift amounts of weight wholly inconceivable by us even when we have the very figures before us: as, for instance, to carry in a minute thirty-seven billion tons of water to the boiling-point from the freezing.

This energy or radiance, this sunshine, comes in undulating beams, or rays, of different wave-lengths, but otherwise all alike, and in open space traveling always at the same velocity—a little more than one hundred and eighty-six thousand miles a second. The leading meteorologists treat it as also of always the same quantity or force; but there is now going on a keen discussion, along with much careful investigation, on that very point. The sun-spot theory, of which the newspapers keep us in constant attention, now seriously, now sportfully, is the most definite branch of this discussion, the question being whether, when the sun's spots are most displayed, its radiance, or energy, is diminished.

Whether the amount of solar energy arriving at the borders of the earth's atmosphere be or be not always the same, certainly the earth's and the atmosphere's exposure to it is always in change. The earth, by its daily rotation on its axis, enjoys the sun's radiance first on one side and then on the other, with a result marked to us unmistakably in the alternations of day and night. Then, while submitting itself to the sun's radiance by sides or strips, the earth in its yearly revolution around the sun submits

itself to the same influence also by belts or bands. The very eye of the sun is, in effect, made to traverse it up and down from a line sixteen hundred miles south of the equator (the tropic of Capricorn) to a line sixteen hundred miles north of the equator (the tropic of Cancer). Of this the effect is marked to us by the alternations of the seasons. Such large variations of exposure produce, in both the earth and the atmosphere, corresponding variations of temperature. In the atmosphere variations of temperature easily become contrarieties; and these and the effort to adjust them make the weather.

Since nothing more regular is known to us in all the universe than the two motions of the earth that determine its exposure to the sun, we might, if ever we got our conception of the weather from the all-familiar primary facts regarding it, expect it to be fairly regular also. It does, in fact, maintain a considerable regularity in its rudimentary manifestations. In the region of the equator, where the days and nights are always of equal length and where the rays of the sun fall always with greater directness than on any other part of the earth, the air is always becoming hotter and more ex-

panded than anywhere else; and the colder, more condensed air about, being under a greater pressure of gravity, is always pushing in, ready, like any other over-pressed thing, to get more space for itself. The hot air is thus forced aloft. Wherever it can find points of escape it drifts off on either side toward the poles. Always cooling as it goes and mingling with other masses of air that will receive it, it becomes itself a part of the more condensed and pulled-upon body and gradually descends and, as far as it may, roots its way back toward the region in which it ascended. For particular particles, though, to return to just the place they started from, if it ever happens, must be a very rare occurrence. The exchange is unceasing, and all the way from the equator to the poles it proceeds with a sufficient regularity to maintain a well-marked system of winds, winds being nothing but defined, more or less horizontal movements of the air, as currents are of water.

The Trade-winds

Of these far the most regular are the trade-winds of the tropics. They so contrast with what we who live in other regions know by our

own experience of wind that they have acquired a great fame and an interest thoroughly romantic. The very name of trade-winds quickens the fancy. Poets have delighted to sing of them, and the school of sea-romancers could scarcely have lived without them. They begin —both north and south of the equator—near the thirtieth parallel of latitude, the parallel that in the north marks a part of our own border along the Gulf of Mexico. By the time the colder air from outside regions reaches the surface in the tropics it has become itself pretty well heated. There is ordinarily just enough difference of temperature between the invading and the displaced currents to effect a displacement.

The trade-winds are the movements of these invading currents. They extend from the surface of the earth up to an average height of about two miles. They are commonly brisk winds, but almost never violent. They have their lulls and shifts; but these are few and slight, and often for days and even weeks at a time they blow without showing in either their direction or their force any notable variation. North of the equator they blow always from the northeast; south of the equator always

from the southeast. They are more pronounced in the winter of their region than in the summer, but they have at no time in the whole year any real cessation.

The two fields of trade-wind activity—the one mainly, but not quite exclusively, north of the equator and the other mainly, but not quite exclusively, south—extend entirely round the earth in fairly well-marked belts. Within these belts lie Mexico and the West Indies, the larger part of South America, a good big fraction of the Atlantic Ocean, most of Africa, of Arabia, and of India; the whole of the Indian Ocean; southern China, northern Australia, the Dutch East Indies, the Philippines, and a good big fraction of the Pacific Ocean. The two together cover, indeed, about one-half of the earth's surface. The regions comprehended in them are largely pure ocean regions, and it is only in these that the trade-winds fully justify their reputation of being the most regular winds and providing the most constant weather in the world. The moment land intrudes there arise diversions and transformations, and these have within their limits often an importance quite equal to that of the main movement. It is due to continental intrusions, for example,

that the trade-winds, both northern and southern, set in at points considerably farther from the equator on the east side of the Atlantic and Pacific oceans than on the west side, and that they show their greatest strength in the south Indian Ocean.

All the grand divisions of the atmosphere, and with them the permanent winds, shift their ground somewhat under the yearly variation in the earth's exposure to the sun. The trade-winds exhibit this characteristic with as much clearness as they do those more peculiar to them. When, as we commonly express it, the sun is coming north the two trade-wind belts follow it northward; and as the sun goes south they faithfully turn about and follow it southward. The range of this movement is different in different sections of the belts, being in some as little as two hundred and in others as much as six hundred miles. At its utmost it is about twenty-six hundred miles less than the sun's own range.

In this movement is included a belt of atmosphere that is not itself a trade-wind region. Before the trade-winds from the north and those from the south actually fly into each other's faces the air in them has become so warm that they die out or are extinguished in the ascending

currents. In consequence of this there is always lying in between them a belt of air of almost no circulation, known as the belt of equatorial calm, or, more familiarly, the doldrums—the thing we all of us sometimes get in, even though we stay out of the tropics. It differs at different seasons and in different localities, but it maintains around the whole earth and through the entire year a breadth of from one hundred and fifty to six hundred miles. It is, though, like the trade-winds themselves, more an ocean than a land condition, and often quite loses its character over the land.

Higher up in the atmosphere, just over the trade-winds, blow the anti-trades, making, apparently, the other half of what thus becomes all through a rather definite system of air circulation. Their direction is exactly the opposite of that of the trades—from the southwest on the north side of the equator and from the northwest on the south side. At the point where these, the upper, winds lose their identity and where the lower, or trade, winds begin to exhibit theirs—that is to say, about the thirtieth parallel of latitude, both north and south of the equator—is another belt of calm. The pair are known as the tropical belts. They are not so

clearly marked as the equatorial belt, but it is in them rather more than in the equatorial belt that we find the scene of those tales which, dealing with ships tragically becalmed and waterless, give youth so often its first relish of literary entertainment. Back, indeed, to such tales is to be referred another name these belts have—that of the Horse Latitudes. The name would seem, though, to belong in strictness only to the northern belt; for the account commonly given of its origin is that vessels carrying cargoes of horses from New England to the West Indies were so often caught in tropical calms and compelled by the shortening supply of fresh water to cast some of the horses overboard as to make the region a byword for this experience.

Owing in some way to the turns and conflicts of the general circulation, the atmosphere shows within the tropical belts always a somewhat higher average weight, or pressure, than appears in any other latitude. In view of this they are often spoken of as the belts of permanent high pressure, and it causes the weather in the regions over which they lie to be prevailingly fresh and clear. The equatorial belt, on the other hand, shows a permanently low pressure—the lowest average pressure shown any-

where except around the poles; and it produces in its region weather prevailingly close and rainy. The northern belt of high pressure, as will appear, plays an important part in our own weather.

The moment we pass out of the tropics the weather becomes even in what are known as its permanent features a far more mixed affair. The sun, even at the midsummer height of its advancement, produces no such equality of heat through the temperate and frigid zones as always prevails in the torrid zone; and in midwinter the permanent gradations of temperature between the tropics and the poles are yet sharper. Consequently, the relations between the cold and the warm masses or currents of air become, outside of the tropics, much more varied and violent. Below the southern tropical belt, near the fortieth parallel, there blows the year round from west to east a wind of such fierceness that the sailors long ago named the region the Roaring Forties, to the subsequent joy and profit of the sea-romancers. Its high constant force is due primarily to the fact that it meets with little land to impede it.

In both hemispheres, between the tropics and the poles there is always prevailing a west

or westerly wind; but in the northern hemisphere, owing to the abundance and diversity of land, it is so often deflected or obscured that probably a large part of the people of the United States live all their lives without ever finding out that the wind that brushes them day by day is prevailingly from the west. Except the trades, blowing from the northeast on the upper side of the equator and from the southeast on the lower side, all of the permanent winds, whether lower or higher, tend to be westerly. That is to say, they tend to blow always toward some part of the east. The lower winds, outside of the trade-wind zone, blow from the northwest in the northern hemisphere, and in the southern from the southwest.

The upper winds—strong westerly—over the two temperate zones create, it is now held, an immense whirl, or cyclone, about either pole. The force of the whirl holds the air back from the pole, and the atmosphere shows at both poles, as at the equator, a permanent low pressure. Out of the great polar cyclones, it is also now sometimes held, are formed, as a sort of satellite, the more ordinary cyclones which, as we shall see, are the main makers

and unmakers of weather in the United States. That our own weather, while remaining strictly our own, has this or some such magnificent far-off connection makes the study of it peculiarly engaging.

The Effect of the Earth's Rotation

Since all of the permanent winds are but responses to the general disposition of the air of colder regions to push down toward the equator and there to rise and move toward the poles, we might wonder why they did not proceed in their business more directly; why they were not, in other words, straight north and south winds. But for that we have all been too well schooled. Who of us can ever forget, after the faithful way in which it was dinned into us in our youth, that the earth, in its daily rotation from west to east on its own axis, travels faster at the equator than at the poles? To the less mathematical or mechanical of us it may never have become a live and really credible conception; but at least we hold it in imperishable memory as a propounded fact. And nowhere does the thing so eminently assert itself as in the movements of the air.

A body of air traveling from the equator toward the poles carries with it an eastward speed acquired at the equator and exceeding always that which it finds in the parts to which it goes. On the other hand, a body of air traveling from the poles toward the equator carries with it, acquired at its place of starting, an eastward speed slower than any that it encounters. The result is that all movements of the air—or, in other words, all winds—of any consequence, under stress of the earth's rotation and its different speed at different latitudes, suffer a twist or deflection, to the right in the northern hemisphere, and to the left in the southern, from the direction they were meaning to take.

To this deflection more than to any other cause is due that aspect of utter wilfulness which the winds show us in our ordinary experience of them. This has found acceptable expression in the Biblical phrase, "the wind bloweth where it listeth." But what makes the wind so generally incalculable is that, in fact, it never does blow quite where it listeth. Like a strong, persistent man, it usually arrives, gets something of what it was after, but not without detours, resignations, and compromises. And since the wind is much the greatest of the

various atmospheric activities that united constitute the weather, all of its adversities and behaviors are those of the weather as well. The wonder of the wind, that under such great perturbations lies a large fixity and order, is the wonder also of the weather. This will show, though, as yet more of a wonder if we consider a little the atmosphere itself—the element in which the wind and the weather originate and reside.

III

A GLANCE AT THE ATMOSPHERE

THERE is nothing in all nature of greater interest to human beings than the atmosphere. That we, the human beings, do not ourselves just find it so is due, no doubt, largely to the fact that we see next to nothing of it. It sticks to the earth on which we live as tightly as we ourselves — has, indeed, as instinctive and deep a dread as we ourselves have of ever getting away. And it sticks to us, to our very persons, as tightly as it sticks to the earth. Our own skins are scarcely nearer or more constant to us. It not only clothes us, but we feed upon it. It is as vital to us as our blood. And yet if some unusually smart person or persons had not discovered the fact and told us we might never have known of its existence. In itself it is practically never perceptible to us; we see it only through what are known as its "impurities."

The word "impurities" has, when applied to the atmosphere, not necessarily the disparagement that it has when applied to some other things—say, to politics or to personal conduct. Anything the atmosphere contains that is not an essential part of its constitution is classed, whether noxious or innoxious, as an impurity. It is always something that the atmosphere catches up from the earth. Perhaps the most prevalent of such impurities is moisture, or water-vapor—one that we could ill spare. The others are commonly grouped, for convenience, under the general name of "dust," because they are apt always to have something of the quality of what we ordinarily know as dust. And it is only in combination with either water-vapor or dust, or with both, that the atmosphere acquires the thickness, color, and glimmer to which mainly we owe our sense of its visibility.

The Constitution of the Atmosphere

When, under some rare prompting, we do bestow a little attention on the atmosphere we find that the fact of its offering us so little to see really enhances its wonder. This thing that to our ordinary perception scarcely exists has as decided a character and as individual a

THE HIGHEST CLOUDS (CIRRUS)

White clouds of fibrous, feathery texture, extended often in long bands or strips, and composed of ice particles. They are the highest clouds and in general lie at a height of about six miles. They are oftenest seen in connection with cyclones, or general storms, and first appear from eighteen to forty-eight hours in advance of the center of the storm.

way of life as the most complex and substantial animal. In every part of the world, on sea, on land, at low levels and at high, the matter of it—that is to say, the air—retains with extraordinary constancy, up at least to a height of seven miles, the constitution of a shade under twenty-one parts of oxygen to a shade over seventy-eight parts of nitrogen.

The air does this in spite of the fact that the two elements are only mixed, never chemically combined. The oxygen continues to be only oxygen, and the nitrogen only nitrogen. If they wrought strictly into each other, drank or ate each other up, and in that way converted themselves into air, then their holding always and everywhere to the one proportion might seem less curious. Nitrogen, to be sure, is a very unsocial, inert element, never eager to combine and always loth to move. It has, indeed, so little activity that scientists wonder sometimes how so much of it ever got into the atmosphere and how, if a need arose, it would ever get out. But oxygen is just the opposite; it likes society and change. The air, therefore, would seem to be a marriage in which the duller and bulkier spouse repressed and controlled the gayer and more roving.

There are quite constant bits of other gases in the atmosphere up to a height of seven miles, and a much varying quantity of water-vapor, the latter playing an important part in the weather. From this height upward the air seems gradually to alter its entire constitution. The nitrogen and the oxygen diminish until, at the height, say, of sixty miles they entirely give out. What then remains is a something so tenuous that it has no perceptible weight and of which the main constituent is probably hydrogen, the lightest of all known substances. Such air would be about as little for a human creature to live on as the promise of a politician. Yet even this slight thing may have its shadow of influence on the weather; no one knows.

Constituted as it is, the air contracts easily and as easily expands. Heat quickly expands it; cold as quickly contracts it. As it expands it cools; as it contracts it warms. The whole atmosphere is held fast to the earth by the earth's force of gravity. But the different parts respond to that force in the most different degrees, according as they are nearer or farther from the earth and according as they are more compact or more diffused. The nearer or the

more compact they are the more tightly they are held. The lower layers have, besides the earth's pull upon them directly, the further compulsion of its pull upon those above. In other words, they have to bear not only their own weight, but that of all the air on top of them. It is a considerable burden.

Extent and Temperature of the Atmosphere

Nobody knows how far up the atmosphere extends. In just the character that it shows at the surface of the earth it continues probably not more than seven miles. But in some form that produces unmistakable atmospheric effects it must continue much farther than that, perhaps even as far as a hundred miles. Its height is, at any rate, enough to produce at sea level, on a surface one foot square, a pressure, or weight, of about a ton. Under this weight the lower layers are therefore normally always the more condensed, the more closely packed; and because of this closer packing they are also normally always the warmer.

This would be the condition of any substance piled high; but it is immensely intensified in the pile that makes the earth's atmosphere, be-

cause of the peculiar behavior of air under the shining of the sun. Pure air, while it retains a large fraction of the solar energy that comes to it and is, so to say, thrown into heat by so much as it retains, has also a strong disposition to pass the energy on to the earth. The land parts of the earth, on the other hand, are perfectly greedy of solar energy. They gulp in all they can get of it and become immediately drunk under it—that is, excessively warm. The earthy matter—the "dust"—which the atmosphere in its lower parts is always catching up has the temperament of its origin, and, like the land itself, greedily absorbs solar energy and grows correspondingly warm. This alone would make the lower layers of the atmosphere commonly warmer than the higher. But they acquire much heat also from the earth itself, partly by direct contact with the hot surface and partly by retaining and converting into heat much of the energy given off, or radiated, by the earth when it cools, and it cools as readily as it warms.

Under the action of these various causes there exists a difference of temperature between the lower and the upper parts of the atmosphere such as hardly seems possible. At the height

of six miles the air is permanently, the year round, colder than at the surface of the earth by about 100 degrees (Fahrenheit). Naturally, under so great a disparity, the warm parts are always more or less in contest with the cold parts for space and place. The one heated, the other cooled to the last point of endurance, each seizes upon the least opening offered by the other toward more grateful conditions.

The contest is sharpest down where the heating is strongest and speediest. The greater storms may attain a height of six or seven miles, but the main storm region extends scarcely as high as two miles. At the height of seven miles the temperature is so low that most of the water-vapor in the air has condensed and, under the weight of condensation, fallen to lower levels. All that remains there is in the form of cirrus clouds, clouds composed wholly of ice particles. From the height of two miles upward the atmosphere is apt to be free of clouds, which indicates a condition of much stability.

The decrease of temperature with ascent is thus continuous and at a fairly steady rate. Even in the lowest and most troubled region this order never gets wholly overthrown. On

or very near the earth there are many local or momentary departures from it. There are also some general ones. In warm, clear weather the temperature decreases with ascent during the heat of the day, but actually increases during the coolness of early morning. In moist, cloudy weather it decreases unfailingly, but at a slower and less certain rate than in clear weather. But in spite of all falters and reversals there is still a prevailing decrease.

Careful observations made by our own Weather Bureau at a number of selected stations in various parts of the country have shown that in the warm months the decrease is at an average rate of 4.01 degrees Fahrenheit per thousand feet up to the height of a mile. The rate of decrease is considerably less in winter than in summer. In both winter and summer it is more rapid according as the elevation is greater, and it becomes considerably more rapid above the height of two miles than it is below. Along with increase in the rate of loss of temperature goes, apparently, also an increase in the velocity of the winds. They have much greater force up near the seven-mile level than they have below.

At or near the seven-mile level we encounter

a surprise. The temperature, instead of continuing to decrease with ascent, remains practically constant at 67 degrees below zero (Fahrenheit) up as far as definite observation has yet extended, which is between eighteen and nineteen miles. The winds, too, continue no longer to gain in force, but are less strong just above the seven-mile level than just below it. At every increase of elevation from the earth up the air loses in pressure, or weight, partly because of diminishing density, but more because of the diminishing depth of the pile. But immediately above the seven-mile level the loss becomes much sharper than at any point below. At the height of eighteen miles the pressure is little, if any, more than a hundredth part of what it is at the surface of the earth.

All of these alterations setting in so suddenly above the seven-mile level are thought to be due to as sudden a change in the constitution of the air itself, to especially a large loss in nitrogen and oxygen and an accession of hydrogen. The line or plane of alteration seems to be everywhere well defined, but it has not everywhere the same elevation. All levels of vertical change in the atmosphere tend, indeed,

to be higher at the equator and to lower in proportion as they approach the poles. It is mainly as they have been observed in our own latitude—the latitude of the temperate zone—that such levels are spoken of here.

Because of its nearly constant temperature the atmosphere from the seven-mile level upward is known as the "isothermal" (equal temperature) region. It is sometimes spoken of also as the region of inversion, under the idea that there the temperature not only no longer decreases with ascent, but even somewhat increases. Not much is known of it as yet; but by means especially of kites and balloons we are all the time coming to know a little more. By kites, altitudes of only about two miles are reached; but by balloons altitudes of more than eighteen miles have been achieved. For the higher flights a small rubber balloon, equipped with automatically recording instruments, is used. As the balloon mounts into rarer and rarer air it finally reaches a point where the pressure of the gas confined in it so exceeds the pressure of the air around it that it bursts. A light parachute with which it is covered then effects the landing of the instruments.

Flying-machines, at the great ascents of which we are all to-day so marveling, count for simply nothing in explorations of what meteorologists set off as the upper atmosphere. One has just now made a new world's record by reaching a height of 19,650 feet, or a shade under three miles and three-quarters. Previous to this the highest flight achieved by a flying-machine was 18,766 feet; and previous to that only 16,400 feet. Flights to heights of more than ten miles are a quite ordinary occurrence with the balloons sent up from the meteorological observatories.

The uppermost or isothermal region is sometimes regarded as a mere vaporous cap, lying sluggishly on top of the true atmosphere, the whole body of it rising and falling a little under the disturbances of the latter, but having, beyond this, no appreciable part in these disturbances. It has presumably no definite outer limit. Its likeliest end would be that of an ill-kept moral resolution—simply to fringe off in some perfectly loose manner. It may at points, by a sort of careless fraying or flirting out, get just beyond reach of the earth's attraction and so lose bits of itself off into space. And it may in the same chance way gain from space

some bits of accession. It may, in its finish, be even a part of space—that hypothetical void which, to do the work it is known to do in transmitting solar energy, absolutely must have something in it.

IV

THE CONFLICT BETWEEN LAND AND WATER

THE atmosphere, it is evident, has much to contend with in its own character. To adjust the differences arising simply from that would require a large amount of weather. But the atmosphere's troubles are immensely aggravated by the peculiarities of the body to which it lives attached—our own curious abode, the earth. Deriving, as it does, much of its warmth and coldness directly or indirectly from the earth, it shares in all of the earth's inequalities in generating and giving off heat. There are many of these, but by far the most important are such as arise from the natural difference in susceptibility to heat that exists between land and water.

No other substance on the earth is so hard to heat as water. It has, in this regard, about twice the obstinacy of land. This being the way in which they are always made, they offer,

in the large bodies of them that constitute the surface of the earth, the most different reception to the rays of the sun that are transmitted to them by the atmosphere. The water has only the smallest friendliness for such rays. A considerable number of them it wholly refuses to absorb and sends them straight back into the atmosphere through which they came. Or, to speak more formally, it *reflects* them. Some of the rejected ones the atmosphere itself absorbs, and becomes heated by them. The others, presumably, return to outer space.

Even to the rays not definitely sent back the water shows but a partial receptiveness. Many of them are permitted only to play on its outermost surface. They raise an evaporation there, and in that may expend their entire energy. It is only the energy of such as manage to get deeper in that produces any heat in the very body of the water. Then of the heat produced there is a quick and generous diffusion. It passes easily from particle to particle by contact; and the movement natural to water is always bringing cold parts and warm parts into contact. Thus the warmth of a part readily becomes, though in lower degree, the warmth of many parts or of the whole.

The land behaves in a manner almost wholly the opposite of this. It embraces with whole heart all the solar rays that come to it, and quickly acquires heat under them to the very limit of all the energy they bring. It has little power of reflection, and so it turns practically none of the solar rays back. It is incapable itself of evaporation, and so it halts none of them, so to say, at the door-sill. All that knock are let in. Yet of the heat into which the land is thrown in such full measure by the visitation it has small power of diffusion. It passes heat on but slowly and with difficulty from particle to particle by simple contact; warm parts cannot drift away and give place to cold parts, as in water; and so the heat in great measure adheres to the portion in which it first arose. Heating so readily as it does and keeping its heat so closely within its own limits, a given surface of land will show, under an equal provocation, two and three and even four times as much heat as a like surface of water. And as readily as the land heats it also cools, while the water, on the other hand, resigns its heat as reluctantly as it acquires it.

On the surface of the earth, one-fourth land and three-fourths water, this constitutional

difference between the two becomes of the greatest consequence. Through the heat of the day, and likewise through the heat of the year, the seas remain commonly much cooler than the continents. Through the coolness or coldness either of the nights or of the year they remain much warmer than the continents. They warm less through the day or through the summer than the continents do, and through the night or through the winter they cool less. The difference between the highest and the lowest temperature for either the day or the year is much less on sea than on land.

The greatest range of daily temperature occurs on dry plateaus. In our own plateau region, between the Rocky Mountains and the Sierra Nevada, the average difference between the highest and the lowest temperatures of the day is about thirty degrees. In the parts of the country where it is least, along the coasts of the Pacific and the Gulf of Mexico, it is much less than this, but is still about eight degrees. There is, however, in our latitude a daily range of only two or three degrees on the open Atlantic Ocean. The average range of temperature through the year within the bounds of the United States is in some places as much as sixty-

five degrees. It is nowhere less than thirty. But on the surface of the great oceans, out far enough to escape the influence of the land, the average difference between the extremest cold of winter and the extremest heat of summer is in our latitude only about eighteen degrees.

How Far Down Land and Sea Warm

Changes of temperature on the surface of the land show no effect ordinarily beyond the depth of a few feet; fifty or sixty feet is thought to be the utmost limit of them. Below this limit temperatures increase rather constantly with depth, but show at any one point next to no change at any hour or season for that point. Temperatures of something over 100 degrees, showing no daily or yearly variation, have been found at a depth of four thousand feet. On the ocean changes of surface temperature are effective to a depth five or ten times greater than on land. Even on the ocean, though, a great part is left undisturbed by them. The average depth for the whole body of the ocean is about two miles. Downward from the depth of about a mile it has practically a constant temperature at something near the point of freezing.

Under the heat of some record-breaking summer day we might find comfort—if we did not find only exasperation—in reflecting that at that very moment only a mile below our own level, spread over three-quarters of the globe, lay a blanket a mile thick and of a coldness only a shade less than that of ice; and that at the same time, some two or three miles above us, lay enveloping the whole globe another blanket fifty or sixty, perhaps seventy or eighty, times thicker than the under one and of a coldness far exceeding that of ice. At least it would define to us on what an extremely narrow stage the heat that to our feeling so nearly for the moment filled the universe really played its part.

The greater cloudiness of the atmosphere over the ocean than over the land tends to increase the difference between them in temperature. Clouds shut out solar radiation and shut in radiation from the earth. Under them a surface, whether of land or of water, heats less and cools less. The greater dustiness of the air over the land than over the ocean tends, on the other hand, to diminish their difference of temperature. Dust is itself absorbent of radiation, whether from the sun or from the earth,

and so of any surface under it rather retards the heating and hastens the cooling.

Viewed simply with reference to their effect on surface temperatures, dust and clouds might be regarded as minor elements which in a measure offset each other. But they are so variable and introduce into the atmosphere itself such confusion that they add greatly to the complexity of the weather. For it is, finally, only as a thing affects the atmosphere that it can have any importance in the weather. Even as fundamental a matter as that of the sharp division between land and water in their surface temperatures would have no effect on the weather if it were not a division shared by the air above them.

It is in our own latitude—in the temperate zone of the northern hemisphere—where great continents and great oceans are most closely intermingled, that the division is widest and productive of its greatest effects. It occasions here a circulation of air between land and ocean as constant and at times and places often quite as dominating as the great fundamental circulation between the equator and the poles. Becoming disproportionately heated in the summer, and especially in the heated part of the

summer day, the air over the land gets pushed in upon at the surface and forced upward by the cooler air from the sea. The lower winds are then prevailingly from the sea to the land. In winter the air over the sea, remaining unduly warm, is invaded and driven upward by air from the land and the lower winds are prevailingly from the land to the sea. The differences are much sharper in winter than in summer, and the winds correspondingly stronger.

Permanent Hot and Cold Piles in the Atmosphere

Inasmuch as the two circulations, that between land and sea and that between the equator and the poles, must be continually skirting and crossing and overleaping and underrunning and often violently combating each other, and since they are both subject to deflection under the overruling force of the earth's rotation, we might expect them to produce between them a confusion in which the wit of mere man could discover nothing definite or calculable. And certainly the result does in no mean degree conform to expectation. Nevertheless, out of all the beating and tossing and whirl there is finally threshed a state of things clear and enduring enough to be quite counted on. In

winter over the center of the great northern continents the air accumulates much as in the same regions ice and snow accumulate in great areas or piles, becoming extremely cold and dry. These piles remain until they are gradually thawed away, so to say, by the advance of summer. Because of their partial durability and because of the superior weight they show in comparison with columns of air in outlying regions, they have come to be known as "the permanent areas of high pressure," or, more briefly, as "the permanent highs."

Over the north Atlantic and the north Pacific are formed, at the same time, large, shallow areas comparatively moist and warm. These, too, keep their place and character through a considerable time, dissipating but slowly under the progress from winter to summer. They are known as "the permanent areas of low pressure." The full establishment of summer sees the situation exactly reversed. Over the northern Pacific and the northern Atlantic now are permanent highs, and over the northern continents are permanent lows. The summer continental lows, however, are seemingly not so well defined as the summer oceanic highs.

While these great areas keep themselves enough in character and shape to have gotten the name of permanent, it is not to be inferred that they are passive or inert. They are known also as "the great centers of action." They have an intimate connection with those smaller, briefer, but still curiously persistent highs and lows which, in their busy succession, give form more or less to the daily household weather in all northern countries, though nowhere else so conspicuously and decisively as here in the United States.

Of the nature and manner of this connection the meteorologists know as yet much less than they wish they did. There is no matter of which they are at the present moment in heartier endeavor to learn more. When of this one thing they have learned more, the mystery of the weather, it is believed, will be much lessened, and the art of weather prediction will acquire an extent and exactness considerably beyond the best it is as yet capable of.

Besides the differences between land and water, very important in making up the weather, especially in its more local mani-

festations, are the differences in the land itself. Flat lands acquire, in a like location, more heat than broken lands, because the sun shines upon them more directly. High lands acquire, when of about the same evenness and location, more heat than low lands, because the higher they lie the more the air over them tends to be free from dust and vapor, and so to allow free passage to the sunshine. Dry land and bare land acquire relatively more heat than do wet land and land covered with vegetation, both moisture and vegetation on the land impeding radiation just as vapor in the atmosphere impedes it.

The air on high mountain peaks is usually cold, because the sunshine is apt to fall on such peaks very unevenly, because the winds keep the air in constant change, and because the air there, being freer from vapor and dust than the air at lower levels, absorbs into itself very little of the radiation from either the sun or the ground. Over high plateaus the air is apt to show in temperature a large daily range, becoming very hot for a little while in the day and then very cold. Always where there is rapid heating there is apt to

be also rapid cooling. Most of the moisture of the land comes to it from the sea under the transport of the atmosphere. The interiors of the large bodies tend, therefore, to be dryer than the borders.

The very multiplicity of the land's unevennesses tends to lessen the extent of the influence of any one of them on the weather. They all, though, give it a turn of their own, more or less effective within the limits of their own several regions; and the larger ones, such as great mountain ranges and great plains, tell a story of wide significance.

V

THE BODY THAT GATHERS IN THE AIR AND MAKES THICK WEATHER

IN all that makes the weather truly flourish —that gives it vigor and versatility and the sharp and never-failing interest of an intricate variety—no country in the world is richer than the United States. The temperate zones—"temperate" only in the fact of being less cold than the arctic and less hot than the torrid regions—are the parts of the earth where the fundamental circulation of the atmosphere between the equator and the poles develops in its exchanging currents its sharpest differences of temperature, and also where it suffers its greatest deflections under the earth's daily rotation. In the north temperate zone, where land and water most sharply divide the earth between them, the atmospheric circulation between continent and ocean attains its greatest force and per-

manence. The United States may be regarded, therefore, as seated at the very center of the atmospheric conflict. And seated there, they offer in their own conformation about all that any land can to complicate and intensify it.

In their north and south extent of sixteen hundred miles they cover about twenty-four degrees of latitude. It is a sufficient length to give in summer two hours a day more of sunlight on the northern than on the southern border. In their east and west extent of twenty-seven hundred miles they cover about fifty-eight degrees of longitude. The sun rises three hours and a quarter earlier on the eastern than on the western border. Much the greatest of all the oceans, the Pacific, bounds them completely on the west, and the second greatest, the Atlantic, on the east. An arm of the Atlantic, the Gulf of Mexico, worthy itself to be called, if not an ocean, at least a sea, washes about half of the southern border, while of the northern as large a part is washed by the Great Lakes, nearly if not quite the largest bodies of fresh-water on the globe.

The western third of the country is occupied

by one of the greatest mountain systems in the world. In its two main ranges, the Rocky Mountains and the Sierra Nevadas, with the continuation of the Sierras, the Cascades, the system traverses the entire length of the country and has at the widest part a breadth of a thousand miles. Great areas in this region lie at average elevations of anywhere from three thousand to ten thousand feet, while of peaks of a height of from twelve thousand feet to that of the highest (Mt. Whitney, 14,515 feet) there are literally hundreds. In the state of Colorado alone there are said to be more than two hundred and fifty peaks of an altitude of more than thirteen thousand feet.

Ridging the country almost its entire length in the eastern third is the Appalachian system: a rather modest affair in comparison with the Rocky Mountain system, but still sufficient to make its projection often felt in the atmosphere and so on the weather. Between the two, running the entire length of the country, and of an average breadth of about one thousand miles, is a region mainly of plain and prairie, of an average elevation of less than seven hundred feet, and with little more than a thousand feet of difference between its lowest point and

its highest point, and watered by one of the greatest river systems in the world.

If with such an extraordinary equipment the United States did not show the world something rather magnificent in the way of weather it would be a great reproach. But they easily save their credit in the matter. Their weather is all that it ought to be. It is as manifold and as locally self-assertive and home-governed as the states themselves, and it is, like them, also nationally instituted and holds itself all together in a majestic overrule.

The Setting Up of a Cyclone

Under the fundamental general movements and exchanges of air there arises in the western part of the country, or more often comes into it from the Pacific Ocean or from northwestern Canada, a body of air less packed together, less condensed, and so less bound to the earth by gravity than the normal. The normal is air that, by the weight or pressure of a column of it resting on the cup of a barometer, raises the mercury in the tube of the barometer to the height of thirty inches.

This height, however, does not represent the

same actual pressure at all places, because the force of gravity itself varies from place to place, increasing from the equator to the poles, but diminishing with an increase of elevation. For a standard, therefore, a pressure of thirty inches at sea-level in latitude 45° has been adopted. Commonly, for convenience, all barometer records are reduced to this by simple calculation before they are reported. Any pressure of more than thirty inches is high, and any of less than thirty inches is low. The range under this gradation is small. Only seldom in the United States does there appear a pressure below 28.9 inches or one above 30.7 inches. One of the lowest ever reported officially is 28.48 inches, the central pressure in the great Galveston storm of 1900. Of high pressures, one of 31.21 inches reported from Montana is perhaps the highest.

A body of air of the kind here spoken of is apt to show, at its first appearance within our borders, a central pressure of about 29.7 inches. Always from the center outward the pressure increases; and the increase occurs with something like evenness on all sides. This characteristic has made it possible to chart the organization in what is familiar to us all as the

daily weather map. Lines are drawn through all the points of observation where the pressure is shown to be the same. The lines become, in most cases, something like complete circles, and the affair appears on the chart as a series of them, separated from each other by varying spaces, but all curving round a common center. Sometimes the lines do not quite join ends and show as circles, or circular figures, with a break in them. In that case the organization is only a weak or half-developed one.

Having arrived, or arisen, the body of diffused air comes along as a part of the constant general movement eastward of the main body of the atmosphere in the middle latitudes of the northern hemisphere. But if it becomes well defined in its quality from the air all around it, it develops in itself a movement of its own. The effort of the denser air around it to thrust into it and share in its less stringent conditions sets up in it a rotation or whirl, and this, its own peculiar movement, gives it a name—that of "cyclone."

The inflowing currents, under the force of the earth's rotation, are carried somewhat to the right of the point toward which they are striving. Then in their haste they somewhat over-

run their goal; and, since the goal is practically one and the same for all, they become more or less obstructive and deflective of each other. The total conflict gets partially compromised by their all falling into a circuit about the point which they are still all eager to reach. The very force of their efforts to reach it still keeps it, though, continually unattainable. Only defeat, as usual, rewards over-striving. The difference of density between the inner air and the outer, in which the whole affair began, gives the inner currents a turn upward and the outer ones a turn downward. The inner air is thus unceasingly carried aloft. A superior roominess—a space of disproportionately low pressure—still abides at the center. The outer air still yields with energy to the attraction of this. Once well begun, the chase thus becomes one that cannot of itself end. By so much as the outer air is drawn down and inward the inner air is driven up and out, and by so much as the inner air departs the outer air seeks to enter.

The locality of the occurrence, meanwhile, is always changing. The air involved becomes, in consequence, all the time a different air. Of the whole body and business the only con-

stant part might seem to be the center, which is in itself little more than a state or condition. Thus the aspect of it all is as if a mere nothing had sprung up and gone stalking about and had set all the world by the ears, as, indeed, a mere nothing has shown before now an ability to do. For days the disturbance goes on and without any change in its essential constitution, and with increase rather than decrease in its intensity. And all the time it is traveling. Commonly it traverses the whole United States east of the point of its origin and part of the Atlantic Ocean, and sometimes also the whole width of the Atlantic and even some part of the eastern continent, before it encounters conditions sufficiently different from those out of which it arose to dissipate and destroy it.

The Difference between a Cyclone and a Tornado

The meteorologists are always at pains to warn us not to confuse, as in ordinary speech we commonly do, the cyclone with the tornado. The tornado is like the cyclone in that it is a body of air in definite whirl about a center. But if measured simply by its size it shows in comparison with the cyclone as only a minute

affair. It has, though, in proportion to its size an extraordinary capacity for business. It tears things to pieces and destroys life with a greediness that makes it justly a terror in the regions which it infests.

The cyclone, on the contrary, is not apt to be in itself violent. It spreads itself out in a large indifferent way, as if, while meaning to possess whatever territory it found attractive, it were too majestic and careless to pillage or destroy. But, like some other majesties, it often carries in its train creatures of a smaller and maligner nature. Of these, the tornado is one, and the worst. It is a mere hanger-on and dependent of the cyclone. It lives and works only under the cyclone's allowance. It springs up suddenly and runs its course with great swiftness, and this is what makes it so destructive. There is never any but the briefest warning of it, and its passage suggests the lightning, which is gone before one can say it lightens.

The cyclone, on the other hand, often forms slowly. The Weather Bureau may have had it under observation for a day or two before feeling justified in pronouncing it a cyclone. After it has in a measure declared itself it usually comes along at considerable speed;

but it is like other large and deliberate bodies, and does not care always to hurry. As if in mere self-indulgence, it sometimes loiters on the way, withholding the activity it is all the time promising and keeping weather forecasters and whole states and thousands of people waiting for it.

The Size and Frequency of Cyclones

The extent of a cyclone is often marvelous. There is a wide variation from cyclone to cyclone, but the average extent has been calculated to be some three hundred thousand square miles. This is an area about equal to that of Kansas, Nebraska, Iowa, and Missouri, with a third of Illinois added. Some cyclones are not so large as this, but some are very much larger. Often a single one is the dominating influence in the lower air all the way from the foot of the Rocky Mountains to the Atlantic Ocean and from Canada to the Gulf of Mexico.

So immensely spread out and so impalpable as the cyclone is, we can scarcely apprehend it as a strict material body, held within its own bounds, active in functions purely its own, and capable of transportation from place to place in the general atmospheric movement without

CIRRUS CLOUDS DIFFUSED INTO A VEIL, OR HAZE

Cirrus clouds of this type are often so thin that they simply give the sky a whitish or silvery aspect and scarcely show to be clouds. They are the kind that produce halos around the sun and the moon.

loss of its individuality. But this, none the less, is what it is. The deep-set, towering mountains over which, oftener than not, we first discover it are not more real, and give, in fact, less evidence of definite, direct power and activity.

These areas of air of abnormally low pressure are crossing the country from the Pacific Ocean to the Atlantic in a fairly close and even procession the whole year through. They are more numerous from the beginning of October to the beginning of April than they are from the beginning of April to the beginning of October. The month in which they are apt to be fewest is June. But even in June there are, on an average, no fewer than eight, or one every three or four days; and in December, January, February, or March, in either one of which they may happen to be most frequent, there are generally never more than eleven or twelve. They take from three to five days for their journey across the country. One can, therefore, practically never look at the daily weather map without seeing printed somewhere there in bold black type the word "Low," which is the word always used to designate the areas of low pressure in charting their locations and progress.

All the areas of low pressure that cross the whole or a good part of the country do not organize into complete and perfect cyclones. But they all have much of the fundamental character of the cyclone. They are all, because of their low pressure, their expansion, drawing in air from surrounding regions and more or less discharging it aloft. They all remain for at least some days fairly well marked, and they maintain during such time a fairly continuous progress eastward. They all make and unmake the weather of the localities over which they pass, varying in this from one another only in their vigor. It is merely their vigor that determines for them whether they shall have what is in strictness the distinguishing cyclonic feature—namely, a continuing internal whirl. Only the more intense ones develop the whirl.

The whirl of a cyclone is always in what, to a person placed at the center of it, would be from right to left, or, as expositors of the subject usually add, in order to make the thing more memorable to us, in a direction contrary to that of the movement of the hands of a clock. This is its direction anywhere in the northern hemisphere; but since the direction is dictated by the rotation of the earth, it would anywhere

in the southern hemisphere be just the other way. In some instances the whirl becomes rapid, but it is not ordinarily so. At the center is a region of calm, but it is never the clearly defined, emphatic, ominous calm that lends such picturesqueness to the descriptions of ocean hurricanes. The passage of the center over a locality does little more than produce in a prevailing storm a slight halt or lull.

The Form and the Qualities of a Cyclone

In form a cyclone is never exactly a circle. Usually it is a not very regular ellipse and shows a length oftenest about double, but occasionally as much as four times, its greatest width. When it first appears in the Far West it is apt to have its length from northwest to southeast, but as it moves eastward it shifts its form and becomes longest from northeast to southwest. Its greatest length may be not more than three or four hundred miles, but is sometimes as much as sixteen hundred, or the equivalent of the distance in a straight line from Texas to Maine.

Mathematically, an ellipse is rather permitted to have two centers, and sometimes a cyclone

has two. But it becomes in such a case so lengthened out and of such crude form that it is usually called a trough. "A trough of low pressure" is a phrase familiar to readers of the daily weather reports, and none too grateful to them, since it is likely to betoken a period of sluggish bad weather. Usually in the formation of a trough a center of low pressure up about the Great Lakes has entered into a kind of trust with one down in the neighborhood of the Gulf, and the combination holds ground in a rather dull, obstructive way, northeast and southwest, over the lower Mississippi and Ohio valleys, a business without, for the moment, any real head. Quite often, though, after loitering inefficiently for a day or two, a trough suddenly pulls itself together and becomes an organization of real form and depth and vigor. Some of the strongest storms experienced in the Mississippi valley and eastward are of this character.

A cyclone owes its life and energy first and last solely to disparities of temperature. But it is not an area of air of evenly warm temperature, ringed in all around by air of an evenly low temperature. If it were that, it might be easier to figure out and explain than it actually

is. The air flowing into it from the north and west is colder, denser, and so of greater force than the air flowing into it from the south and east. Therefore, of the winds it raises those from the northwest are the strongest. Next in strength are those from the southeast, then those from the southwest, and then those from the northeast.

A fair illustration of the matter is furnished by a winter cyclone (winter cyclones show stronger, as a rule, in all features than summer cyclones) that, while central near the mouth of the Ohio River, produced surface winds of from eight to twelve miles an hour in its central region and of from twenty to thirty-eight miles an hour in its northwest, from eighteen to thirty in its southeast, from eighteen to twenty in its southwest, and from twelve to sixteen in its northeast region. On all sides the winds increase in strength as they near the central area of the cyclone. Low down they are locally more or less affected, though, in both their direction and their force by the irregularities of the ground.

The cyclone reproduces in its own temperature the difference of warmth in the various invasions which it suffers. In the region

covered by its northwest quarter the average temperature will be much lower than in that covered by any of its other quarters. In the region covered by its southeast quarter, on the other hand, the average temperature will be much higher than in any covered by other quarters.

Up to a considerable height the cyclone retains unimpaired all of the characteristics that mark it below. It still shows a clear flowing in of air from all sides and upward from the center. The temperatures lower quite regularly with every increase of altitude, and the air becomes in all quarters colder; but the distribution of temperatures among the several quarters remains about the same. The winds all increase greatly in strength, becoming at the height of two miles from two to three times as strong as they were at the ground. At that height, though, or even somewhat below it, the winds from the west begin to show much the greater increase, and from there upward the traces of winds from the east grow fainter and fainter, until finally the whole organization becomes blurred and then blotted out in the permanent flow of the general atmosphere from west to east.

Three miles, or at most four, is now rated to be about the full upward limit of American cyclones. At that height they become absorbed in the constant eastward flow of the general atmosphere, and, while they may there somewhat retard or deflect that flow, they retain no longer their own characteristic flow upward. This causes them to be accounted shallow disturbances, and leaves them, as regards size, preeminent only in their area, or horizontal extension. The European cyclone, which in comparison with the American is regarded as not much of an affair, has, in general, a height of something over five miles, and the tropical hurricane, also a cyclone, though of a somewhat different order from the temperate-zone cyclones, and of not more than one-third the breadth of the American cyclone, shows sometimes a height of more than six miles.

In view of the immense extent and long persistence of the American cyclone, its shallowness adds greatly to its strangeness. The question asked in effect by Dr. Hann, the eminent Austrian meteorologist, how such a "paper-thin" and so spread-out (*eine derart papierdinne aber so ausgedehnte*) air area can so perfectly and for so long maintain itself is the question asked

by all meteorologists. The answers they have thus far given to it are not, it must be said, as full and clear as could be desired. They themselves acknowledge in the matter a mystery which they have not yet entirely resolved.

VI

HOW THE STORM BODIES TRAVEL AND DO THEIR WORK

OF the hundred and ten or twenty areas of air of low pressure that come into clear existence and traverse a considerable portion of the country in the course of a year as many as forty come in across the northern border of Montana from the Canadian province of Alberta. About twenty come in straight along the northern border of the country from the north Pacific Ocean. Some nine or ten first declare themselves over the north Rocky Mountain plateau, and twelve or thirteen somewhere in Colorado. Thus quite two-thirds of the whole number arise or first appear in the extreme northwest quarter of the country. Of the other third from twelve to fifteen are southwestern in their origin, two or three a year coming in from the south Pacific coast and ten or twelve arising in Texas. Six or seven are

apt to spring up in the east Gulf and south Atlantic region, and a like number in the region of the mouth of the Ohio River.

In much the larger number of instances it is, therefore, from somewhere along the line of the Rocky Mountains that our cyclone begins its visible course. Wherever it sets out it betrays always a clear desire to travel into the valley of the St. Lawrence River and thence out to sea. Most times it wholly succeeds in this desire, and a consequence is that "the valley of the St. Lawrence," according to a statement of General Greely, former chief of the United States Weather Bureau, "has the largest number of storms of any section of the globe."

Like all other earthly bodies, though, the cyclone gets its way only by compromise with various hindrances. Often it is permitted to go to the St. Lawrence by the straightest path, but about as often it is compelled to make large detours. What draws it toward the St. Lawrence is the permanent eastward drift of the general atmosphere. This is thought to be particularly strong, even, perhaps, at its very strongest, in the latitude of our northern border. The cyclone, if under no other compul-

sion, yields to it and as quickly as possible comes into line with it at the point and in the direction of its greatest strength.

No matter whether the cyclone arises near the northern border or in the far Southwest or on the south Atlantic coast it still shows this overmastering urgency to get into the full tide of the general eastward drift. But it is very apt to have near it another more or less organized body of air of exactly the opposite character. This is what is known as an area of high pressure, or an anticyclone—a body in which the air, more condensed and forceful than in the cyclone, is flowing downward and outward. In nearly all cases where a cyclone departs from the straight path it is attracted or diverted, the belief now is, by an anticyclone.

Even in its deviations, however, the cyclone shows a very appreciable regularity. It has been studied and charted with the utmost minuteness in its various tracks. No deeply concealed human fugitive was ever run down more triumphantly by the most patient and acute detectives. And it has been found to depart in any of its courses very little from one or the other of two general lines. When it does not travel pretty straightly away to the St.

Lawrence valley it makes a dip southward somewhere along the eastern slope of the Rocky Mountains, and then, turning, proceeds quite directly northeastward. And in its dip it does not stray beyond certain limits. When it sets out from either Montana or the north Rocky Mountain plateau it never gets farther south than northern Kansas. When it sets out from either Colorado or Texas it makes almost no dip at all, but strikes nearly at once into a true northeast course.

It gets an aspect of pure waywardness only when, starting on the north Pacific coast, in the state of Washington, or on the south Pacific coast, in southern California, it beats southeast almost straight to Texas and the Gulf of Mexico. No doubt, in such a case the immense ruggedness of the country combines with a more than ordinary obstinacy in the surrounding masses of air to drive the poor cyclone quite mad. But the case happens very rarely—not oftener, perhaps, than two or three times in the course of ten years. The limits, indeed, within which the cyclone commonly confines its course are comparatively so strict and narrow that it is usually spoken of as traveling by either its northern or its southern circuit, the northern being the

straight and shorter way and the southern the curved and longer.

Preferring always the northern circuit, the cyclone finds itself much less thwarted in this preference through the summer and early autumn than through the winter and early spring. It is then, owing to the wide and fairly even spread of warmth over the northern hemisphere, less subject to the push and pull of large, strong areas of air of high pressure thrusting down from the cold north. It is itself, at this season, rather a mild body, little inviting conflict or opposition, and moves along with comparatively slight disturbance by the way it best likes.

The Government charts in which the cyclone's courses at different seasons are all graphically portrayed show for midsummer little more than a simple succession of almost straight lines. For midwinter, though, the portrayal is such a network of curves and crossings that at first glance it might seem to offer not the least trace of law or order. A closer look will soon clear it up. The courses nearly all loop more or less southward; but they still keep within rather clear bounds and come finally all into one general direction—northeast.

The Speed of Cyclones

In either circuit the cyclone travels with a speed always closely correspondent to the degree of its own perfection. If it is a complete cyclone and of extreme intensity it may make as much as sixty miles an hour. But if it is feeble in its organization it may not make more than fifteen. It presents itself in strong form more often in winter than in summer. It shows, therefore, a higher average rate of speed through the winter half of the year than through the summer half. For the latter the average rate has been found to be a little over twenty-six miles an hour, and for the former a little over thirty-two.

In general, a cyclone starting from Montana, if it chooses the northern circuit, will have come, at the end of its first day's travel, nearly to the eastern border of North Dakota. At the end of the second day it will be centered somewhere over Lake Superior. The third day will carry it well into the St. Lawrence valley, and the fourth day will bring it the Weather Bureau's familiar dismissal, "Passed out to sea." If it chooses the southern circuit and drops down into Kansas or Missouri it will be a day longer

on its journey. It is apt to show, though, greater speed on the southern circuit than on the northern. Starting from western or southern Texas, it often goes with great rapidity, reaching the St. Lawrence valley in three days.

It may, however, when traveling by the southern circuit, miss that much preferred region entirely. The strain of its deflection southward may keep it from turning back soon or sharply enough to get as far north as the St. Lawrence valley before it is carried to the Atlantic Ocean. It will still go on, though, in a clear northeast course, intent as ever to come into line with the swiftest part of the general upper eastward drift. And its failures to reach at least some border of the St. Lawrence valley are, all told, very few. For the last stage of the journey the path most trodden is a line running about midway between New York City and Buffalo, about midway between Boston and Montreal, and a little north of Halifax. People living along that line may boast or complain that they get in the matter of weather about all that is to be had in the whole United States.

While well-formed cyclones almost never fail to reach the Atlantic Ocean, only very

rarely are they able to cross it. They at once lose speed, slowing down to an average rate of about nineteen miles an hour, and are apt before the passage ends to become entirely blotted out. Of the few that do get across not more than one in nine touches Great Britain or the middle part of the western coast of the Eastern Continent. The others, under their strong northeastward impulse, are carried to Iceland and the coast of Norway and, if they still survive, across northern Russia. Never one, it is affirmed, holds out all the way to the eastern coast of Asia.

Authoritative practice makes the word "cyclone" almost interchangeable with the word "storm." The practice, though, does some violence to the associations of ordinary usage. A fully formed and even strong cyclone may travel all the way from Montana to the St. Lawrence valley and produce practically no rain. This makes, to our every-day conception, a rather empty "storm." To the meteorologist "storm" is almost exclusively a matter of wind. But even in the raising of wind the cyclone may fall much short of the usual idea of storminess. It may be quite able to travel and to draw the air into it from over a wide

area and still raise the wind to nothing more than freshness—that is to say, to a force of not more than eleven or twelve miles an hour. Yet all the time and all over the country, at least anywhere east of the Rocky Mountains, the winds are more or less under the control of the cyclone and its co-partner, the anti-cyclone. And as for rain or its winter equivalent, snow, there is east of the Rocky Mountains never a truly great fall that it is not due directly to the passage of a cyclone. Even the larger number of what are classed as local rains arise only out of conditions that the cyclone has made for them. The cyclone is not itself a traveling body of either rain or wind or of weather of any sort. But it arouses and drives along much the greater part of all that we commonly have in mind when we speak of stormy weather. What it shall accomplish in this way will depend very much on what it encounters in its progress. Its grand function is to set things off.

Change in Winds and Temperature at the Approach of a Cyclone

In any region upon which a cyclone is advancing its earliest effect is likely to be a shift-

ing of the winds. Instead of blowing, as in quiet weather they most commonly do, from the northwest, they will begin to blow from some point between northeast and south. During the day, in summer, along the Atlantic and Gulf coasts the effect might be less to alter the wind's direction than to increase its force; for there the wind during the day, in summer, comes usually from the sea and would be likely to have already about the direction which the cyclone tends to establish. In other localities as well some special condition might check or thwart the general tendency. But at most places anywhere in advance of the cyclone and within its influence the winds would be pretty nearly reversed. And this effect might appear as much as a thousand miles away from the center of the cyclone.

As the center of the cyclone comes nearer the wind increases in strength. It continues at the same time to alter its direction, until by the time the center of the cyclone has passed it will be coming from the northwest. Just in its first descent from this direction it is likely to show itself at its very strongest; for it is in the northwest wind, just at its entrance into the central region, that the greatest force of wind

anywhere about the cyclone is usually found. But as the cyclone moves away the wind, while continuing from the northwest, will gradually diminish. At places lying in the upper, or left-hand, half of the cyclone's course and influence the wind will "back"—that is, go by the north—into the northwest; and at those lying in the lower, or right-hand, half the wind will "veer"—that is, go by the south—into the northwest.

Almost simultaneously with the first shift of the wind in advance of a cyclone the air begins to show a change of quality. Before this has yet become apparent to our feelings it is marked by the barometer. The barometer begins steadily to fall, showing that the air is losing weight, or pressure, and, also, that it must be growing both warmer and moister. Very soon, though, the change begins also to be felt. The weather becomes sensibly warmer and less fair. Often a cyclone, while it is still centered somewhere on the eastern slope of the Rocky Mountains, will already have produced leaden skies and higher temperatures over the whole country east of it. It is apt, though, to show its first effect on the temperature at points farther away from its center than the farthest to which it sends out its clouds.

The clouds that give earliest notice of it are the long, thin, fringy, light silver clouds familiarly known as cat's-tails or mare's-tails, and scientifically as cirrus. They have usually the look of being, as they always are, cold and high up. Air sent far aloft in its discharge from the center of the cyclone encounters such coldness that its moisture is condensed, not into water particles, but into particles of ice. Of the clouds so formed parts are sometimes swept a little to the rear of the cyclone, but the main body is caught up and carried eastward in the movement of the general atmosphere.

It is the same movement that controls the progress of the cyclone. But the cyclone is more or less turned aside and held back through being tied at one end to the earth. The cirrus clouds, lying far above such retardations, soon acquire pretty nearly the speed of the movement itself. About all we know of that speed we learn, indeed, by measuring the rate of travel shown by the cirrus clouds. They so far outrun the cyclone that at their easternmost extension they may be as much as two or three days ahead of it. They are a sure sign of its coming. But they do not mark with any great exactness within what time it will come.

As soon as bodies of warm, moist air begin to be drawn westward and northward from the east and the south they come into contact with bodies somewhat dryer and cooler. With these, little by little, they share their superior warmth, and it is in this way that the general temperature is raised. But in the process their own temperature is lowered just enough to make the amount of moisture they were originally charged with too much for them and to set it condensing into clouds.

In advance of a cyclone clouds of this kind may begin to arise before the cirrus clouds appear. At first, though, they are such as might arise from some disturbance more temporary and local than a cyclone; and it is only as the cyclone gets comparatively near and they spread out and thicken that they grow into a clear sign of its coming. They may, by their spreading out and thickening, check the ordinary daily radiation of heat from the earth and the lower atmosphere, and thus increase locally the rise of temperature provoked in the first place by the cyclone. This rise sometimes becomes as much as thirty degrees above the normal.

In both increased warmth and increased cloudiness the cyclone becomes locally more

manifest as it gets nearer. As soon as the center of it has gone by the temperature begins to diminish. The warm currents from the east and south give place to the cold ones from the west and north, and at the first touch of these the weather at any given place becomes cooler. But of cloudiness a cyclone often has a considerable extent behind it, though less than before it. The extent both before and behind varies with the intensity of the cyclone, but amounts on an average to a prevailing cloudiness for from four hundred to six hundred miles on either side from the center. In a well-organized cyclone, central over the lower Ohio River, there will be a pretty complete cloudiness from the upper Lake region to the Gulf of Mexico and from eastern Kansas to the Atlantic Ocean.

How the Cyclone Produces Rain

The conditions which produce cloudiness all about a cyclone also produce rain if only they are strong enough. The capacity of a body of air to carry moisture, or water-vapor, without spilling any is always in proportion to its temperature. Air at a temperature of fifty-one degrees can carry securely twice as much as air

at a temperature of thirty-two degrees. When, as about a cyclone, warm currents laden to nearly their limit with moisture run swiftly into the face of colder currents that are, perhaps, themselves, in proportion to their temperature, not overdry, sharp disparities between temperature and moisture are bound to follow. They follow also upon the rapid cooling of the air in its constant rise from the center of the cyclone to higher, colder levels.

The only way to set things right in such a case is through condensation. If the need is not too strong, condensation simply into clouds, to be blown off and finally dissolved in areas of air that can accommodate more moisture, will quite suffice. But if the need is stronger, resort must be had to the extreme remedy of rain—to a complete, undisguised spill. Very rarely does a well-formed cyclone traverse the country without somewhere producing rain. But the amount it produces depends not a little on where it starts and by what route it travels.

In northern Montana, east of the Rocky Mountains, the air tends always to be comparatively dry. The currents coming in from the Pacific Ocean, moist at the outset, lose much of their moisture under contact with the

mountains. Currents from the Gulf of Mexico and the Atlantic Ocean, the only other considerable sources of moisture, are apt not to reach that far northwestern region, and when they do they will have dried out more or less on their journey. Currents from the Great Lakes have at most no extreme amount of moisture. It is owing to the condition thus established that occasionally a cyclone going eastward from Montana by the northern circuit produces practically no rain.

This is likeliest to occur in the months of October and November, a season when the northern cyclone is rather uniformly well defined and vigorous. Usually it does produce rain, but it is apt not to produce much until, if it is going by the northern circuit, it has come into the region of the Great Lakes, or until, if it is going by the southern circuit, it has gotten pretty well south. The truly great rains are produced, as a rule, by cyclones from the southwest, especially those arising in western Texas or on the western border of the Gulf of Mexico. In these the contest is likely to be from the very start between currents all of a high degree of moisture.

In form the rain area is of the greatest irreg-

ularity. Like the cloud area, while more or less completely surrounding the cyclone, it has commonly a wider extension forward then backward. The extension forward has been thought to show a proportion to the rate of the cyclone's progress. Before a cyclone moving at the rate of fifteen miles an hour the rain area, it has been estimated, will reach out something more than four hundred miles, and something more than six hundred miles before one moving at the rate of forty miles an hour.

Not only the area, but also the fall, of rain is greater in advance of the cyclone than behind it. Oftener than not the point of heaviest rainfall is rather directly on the line that the center of the cyclone is to follow. In view of this it has been argued that by taking up the heat, or energy, set free by the fall of rain the cyclone always maintains in its rainiest quarter a strength greater than in other quarters, and that, under the force of this, it is all the time forming for itself a perfectly new center just along the line of the greatest rainfall. But the general opinion now is that, while the cyclone does get some addition of energy from the fall of rain, it owes to this none of its fundamental organization and movement.

Between its own inner strength and the volume of rain produced there appears no clear correspondence. Often a cyclone of no very low air pressure at the center is accompanied by heavy rain. The rain seems to be really but a local outburst even when it marks the cyclone's whole course. It is more at one time and place and less at another, according to the condition of temperature and humidity offered just then and there to the cyclone at its approach.

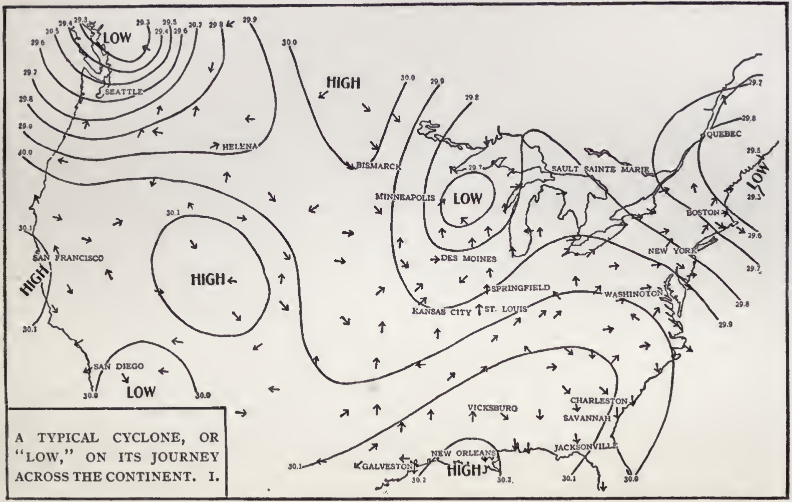
There has been discerned, however, a diurnal period both in the progress of a cyclone and in the rainfall. The cyclone's advance is apt to be a fourth more rapid through the latter part of the afternoon and during the evening than at other times of day, and it is also in the latter part of the day that we get most rain. In this the rain and the cyclone probably do not much influence each other, but are both influenced by the daily decline of the sun.

It is due especially to the fitfulness of the rain areas that the official weather forecaster wins from his public so seldom any but words of disdain. No man serves with more faithfulness and intelligence; few men are of more direct and practical use in the world. But because he cannot tell us just to the minute

when to wear our rain-coats or carry our umbrellas we all incline to regard him as a quite futile and ridiculous person. The moment even a quite dim cyclone appears anywhere in the country he knows of it and reports it. He tells precisely where it is to-day and with fair precision (in most instances) where it will be to-morrow. He describes it in all its qualities and force. He predicts with some certainty what is to be the general scope and direction of its rain tract. But because this tract is bound to narrow and widen, bow in and bulge out, in a way that no one can foresee his rain predictions must be for many places, especially along the borders of the course, no more than probabilities. He frankly offers them for no more. But at any place where they happen not to become fully realized the discontent is as great as if they had been solemn pledges.

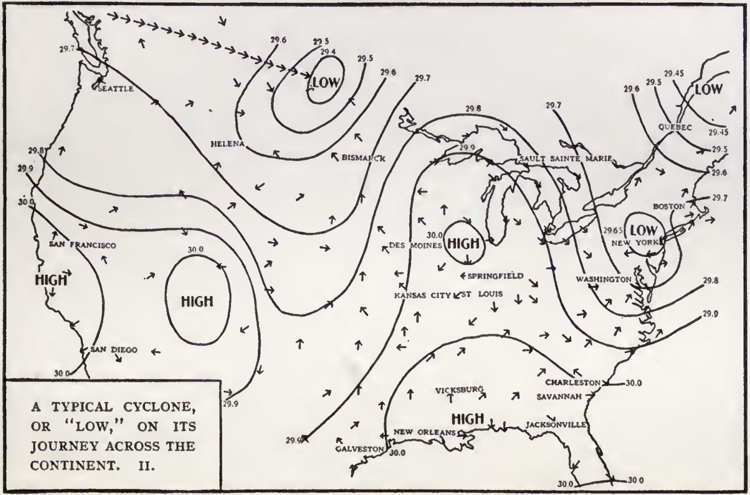
If the matter were better understood this would not be so. No one can follow the work of the Weather Bureau with any care and not be brought to wonder that, of a thing so largely hidden from the eye and apparently so without order as the weather, so much can really be told and foretold. The Weather Bureau, indeed, is an institution toward which we ought to be at

pains to cultivate a better loyalty. It has, I fancy, a need of all the friends it can win. It is not political; it has no part in the elections except, perhaps, to be condemned when Election Day turns out nasty. Consequently, when it appeals to Congress, the one source of its livelihood, and at the same time a body to whom nothing else is quite so vital as the elections, it gets, no doubt, never any too eager a compliance.



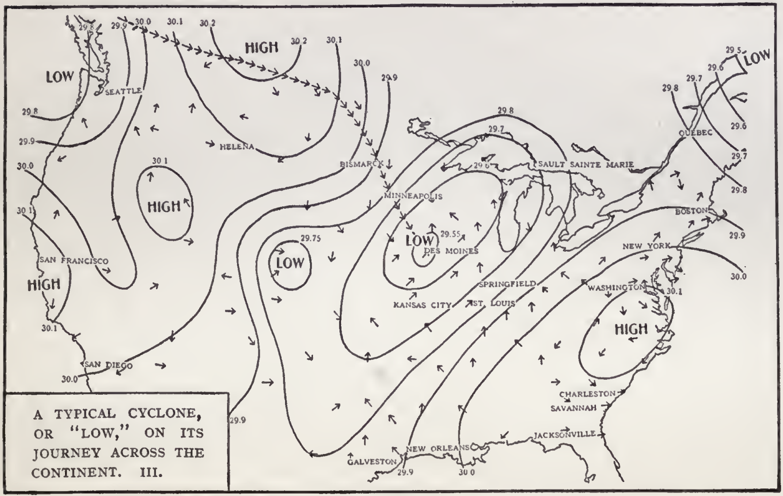
A TYPICAL CYCLONE, OR "LOW," ON ITS JOURNEY ACROSS THE CONTINENT. I.

The cyclone, or "low," appears on the Pacific coast north of Seattle, its position on the morning of November 7, 1910. The succeeding maps show its position each morning thereafter. The arrows show the direction of the wind about the several "highs" and "lows." The curved lines (isobars) connect places of equal air-pressure; the figures state the pressure in inches.



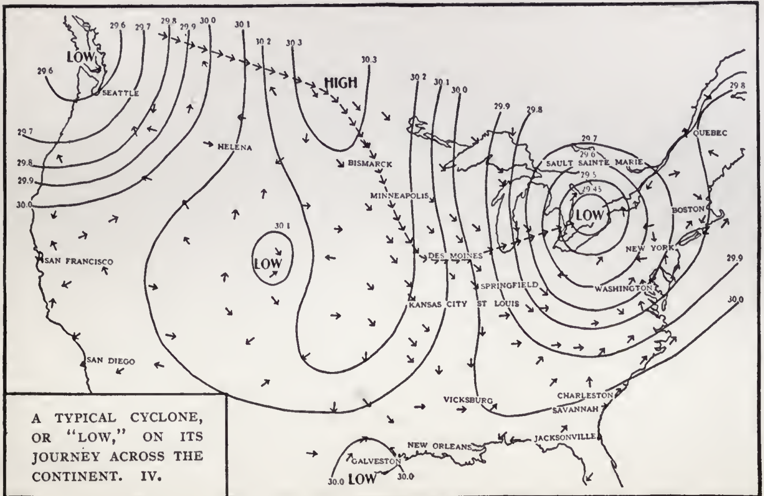
A TYPICAL CYCLONE, OR "LOW," ON ITS JOURNEY ACROSS THE CONTINENT. II.

Morning of November 8, 1910. The cyclone, or "low," has traveled in twenty-four hours from the Pacific coast to a point northwest of Bismarck, North Dakota. The line of arrows shows its course. It has caused rain through the states of Washington, Oregon, and Idaho, and warmer weather through the Rocky Mountain region and the Southwest.



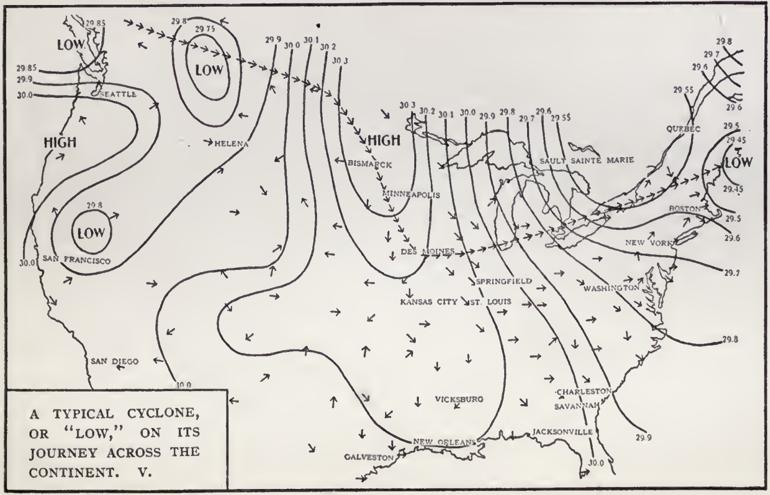
A TYPICAL CYCLONE, OR "LOW," ON ITS JOURNEY ACROSS THE CONTINENT. III.

Morning of November 9, 1910. The cyclone, or "low," has come in its second day's travel from northwest of Bismarck to Des Moines, Iowa. The rain area has extended eastward into Minnesota. The weather has grown warmer through the whole Mississippi valley, but colder in the far Northwest, at the rear of the cyclone.



A TYPICAL CYCLONE, OR "LOW," ON ITS JOURNEY ACROSS THE CONTINENT. IV.

Morning of November 10, 1910. Its third day's journey has brought the cyclone, or "low," from Des Moines, Iowa, to eastern Lake Erie, with rain southward over the Ohio River valley, and eastward through the state of New York and New England. There has been no rain whatever from this storm in the far South.



A TYPICAL CYCLONE, OR "LOW," ON ITS JOURNEY ACROSS THE CONTINENT. V.

Morning of November 11, 1910. Having finished its fourth, or last, day's journey, the cyclone, or "low," is now disappearing off the coast of Maine. Colder weather prevails in the Mississippi valley and eastward, due to the anti-cyclone, or "high," central north of Minneapolis. But along the Atlantic coast the weather is as yet only on the turn to colder.

VII

THE BODY THAT SCATTERS THE AIR AROUND AND MAKES FAIR WEATHER

THE weather is so much more impressive to us in its stormy than in its fair manifestations that we naturally give the atmospheric organization which specially produces these the foremost place. This organization, as we have just seen, is the cyclone. But there is another atmospheric establishment that in the making of the weather is of quite as much importance as it. This is one in which the air, under the force of some overcharge up in the region of the permanent eastward drift of the general atmosphere, spills down and then runs out, flooding, as it were, a great area of the country. Coming for the most part from very high up this air is prevailingly dry and cool and the spread of it produces fresh, fair weather.

The overreaching of the currents in their haste to get into the central pour, added to the

deflecting force of the earth's rotation, sets the whole organization, just as in the case of the cyclone, into more or less of a whirl. But since the central pour is a descent instead of an ascent, a draft down the chimney instead of up the chimney, as in the cyclone, the direction of the whirl is just the opposite of that of the whirl in the cyclone. It is what, to a person placed at the center, would be from left to right, or the same as the direction of the movement of the hands of a clock. Because of this complete reversal of the movement of the cyclone the organization is known as an anticyclone.

It is also known as an area of high pressure, or, briefly, in weather reports and maps as a "high." This marks another and a more fundamental contrast which it offers to the cyclone. Whereas in the central region of a cyclone the air always shows, as weighed by the barometer, a pressure, or weight, below the normal—that is, something below thirty inches —in the central region of an anticyclone it shows always a pressure of something more than thirty inches. This excess may be very slight. In the larger number of instances the highest pressure shown is only 30.2 inches. This marks a rather feeble organization and is

especially frequent in summer anticyclones. But even in strong winter anticyclones a pressure as high as 30.8 inches is rare, a record made, perhaps, two or three times in a year. Nevertheless, a pressure of 30.9 is not startling, and pressures yet higher do sometimes occur. One of 31.42 inches reported from a Canadian station just beyond the northern border of Montana is nearly, if not quite, the highest ever reported from any part of the region of observation covered by our own and the Canadian weather service.

We have vaunted, and with good warrant, the great extent possible to the cyclone. But in this the cyclone cuts only a small figure beside the anticyclone. An anticyclone may not only extend from ocean to ocean and from Canada to the Gulf, but also so far overrun the borders of the country that on the weather map, which is limited pretty nearly to the United States, it appears as boundless. Yet it will not be boundless. It will not be just an atmospheric condition spread lawlessly about and shading off imperceptibly into nothing. Its outer definition, to be sure, will nowhere show with such distinctness that one could travel to it and from direct observation say

"Here the thing ends." But with whatever dimness, there will still be an individual area decisively marked off within which all the movements of the lower air have relation and symmetry to a whirling core where the air from high levels is in steady descent and outflow, and the whole organization will be capable of progression.

Form and Movements of the Anticyclone

There are, however, in the areas of high pressure, as in those of low pressure, all degrees of development, beginning in what is scarcely more than a disposition and ending in a complete organization; and they often achieve quite a career and prove themselves quite efficient anticyclones without coming to full perfection. At their best they never show the trim, close, intense formation of which the cyclone is capable. Being fairer in their effects than cyclones are, they enjoy, on the whole, a better welcome. But they are not near so piquant or picturesque, unless, indeed, we should think of them—and this we well may—as having the amiability and informality that go with the best kind of largeness.

As charted on the weather map the cyclone often shows nearly the form of a true circle, with the air pressure increasing from the center outward on all sides by the sharpest and yet perfectly regular gradations. In what is, perhaps, its trimmest form the anticyclone has been described as a triangle with the corners rounded off. It shows oftenest as a long, rather uncertain oval. The air flows constantly out from the center on all sides, and the pressure constantly decreases from the center outward. But the decrease of the pressure is by grades wide and easy and of uneven extension, and the movement of the air is, in consequence, gentle. Not until the currents have reached the borders of a cyclone, where the abnormally low pressure within the cyclone offers them, as it were, a swift run downhill, do they, as a rule, attain a stormy velocity. They very often attain it then, and simply their eager inrush is what makes the high west and northwest wind always encountered on the west, or rear, side of a strong cyclone.

Whereas the cyclone is an area of warm air, the anticyclone is an area of cool air. But as in a cyclone the air is not of like warmth throughout, so in an anticyclone it is not

throughout of like coolness. The north and west quarters of an anticyclone are, as a rule, warmer than the east and south quarters. The air is extremely cold in the earlier stages of its descent, for the descent commonly begins up at a height of about five miles. The depth of the anticyclone is, therefore, nearly double that of the cyclone. The outflow is not all at the lower levels, but appears even high up. The organization as a whole is, as it were, an inconceivably deep cell, or funnel, built up out of air and with air flowing through it, but permitting more or less leakage all the way from the top to the bottom.

Like the cyclone, the anticyclone makes its first appearance commonly in the Far West. Either it arises somewhere on the northern Pacific coast or it comes in from Alberta, the Canadian province lying just north of the states of Idaho and Montana. The latter is by far its more frequent course. From Alberta, it will be remembered, come also the larger number of cyclones. But when entering from Alberta the anticyclone does not, like the cyclone, enter almost exclusively by way of Montana; it may come in through North Dakota or Minnesota or over the Great Lakes, or even east of them.

Occasionally it becomes a strong influence in the United States without actually crossing the border.

Having touched or crossed the border, the anticyclone shows, like the cyclone, a decided preference for a direct eastward course. Yet, like the cyclone, it often drops down into the southern circuit, and, traveling that circuit, it is much apter than the cyclone to leave the country at some point on the middle or south Atlantic coast. When it arises on the Pacific coast it may move eastward along the northern border until it has crossed the Rocky Mountains, and then proceed by either the northern or the southern circuit. But it may take at once a strong southeastward course, and, crossing the mountains by way of Colorado, proceed rather directly to the south Atlantic coast.

The anticyclone, then, follows in general about the same courses as the cyclone. But it does not follow them with as much energy. It betrays more often than the cyclone a disposition to loiter, and when it travels it travels with less swiftness. Its average rate of progress has been calculated to be in winter twenty-seven miles an hour to the cyclone's thirty-two, and in summer twenty-one miles an hour to the

cyclone's twenty-six. Its ordinary passage over a given place is about a day longer than the cyclone's. When one is traveling directly upon the heels of the other, as is oftener than not the case, a period of six or seven days will cover for both the whole coming and going and see the way clear for a succeeding couple And inasmuch as the almost constant succession of such couples is what, more than anything else, determines the weather from day to day over all the country east of the Rocky Mountains, it long ago became common observation that our weather comes to us in periods of three days.

How Cyclones and Anticyclones Work Together

While in the ordinary way a cyclone is directly followed by an anticyclone, yet it is not so always. Before the anticyclone has definitely diffused over the country its clearing and freshening effect there has arisen somewhere and come into sway another cyclone. This puts the weather out of half its order and gives to every-day human experience an added proof that most of the annoyance of life is due to the fact that things will not adhere to their habit. There is for the time not an entire

obliteration of the three-day period, but a kind of blurring and bunching up, with a passage of bad weather succeeded, not by good weather, but by another passage of bad, and with so little break between that the two show as one and so become to human patience quite outrageous.

This is an irregular proceeding, but of course it is in itself quite as natural and lawful as the other. The cyclone, according to the opinion now most held, is not so much the partner of the anticyclone as its creation and servant. It is formed always on the edges and under the force of the anticyclone. Even if it arises, as it often does, when an area of high pressure is definitely marked nowhere in the country, it is believed to be due to the influence of such an area, an influence felt before the body exerting it becomes visible.

The fundamental exchange and distribution of air between the hot equatorial and the cold polar regions is thought to be going on with more abundance and vigor just over the northern part of the North American continent than perhaps anywhere else in the northern hemisphere. It happens just here with especial frequency, therefore, that under the disparities

and stress of this exchange and distribution air is driven down to the earth in the form of anticyclones. To relieve the stress and disparities which they themselves produce below the anticyclones set up the cyclone, and by it so much of the air as proves to be out of place and not desired below is carried aloft. If one cyclone is not enough to do the work they set up two, or whatever number may be required. Consequently, the cyclones very often outnumber the anticyclones. If the number of cyclones crossing the country in the course of a year is, say, a hundred and ten, the number of anticyclones crossing is likely to be about ninety. They are distributed through the year in much the same proportion as the cyclones, varying from an average of four in June to an average of from ten to twelve in January and being considerably more frequent and more potent through the whole winter half of the year than through the summer half.

An anticyclone of real influence never fails to diffuse over the country clear weather and gentle winds. Under its advance the temperature falls, dropping in extreme cases as much as thirty degrees below the normal. Under its departure the temperature gradually

rises. Under its presence the general body of the air, being then dry and without much motion, gives the sunshine free access to the earth, which thus acquires more heat than it otherwise would and imparts more to the air that lies in contact with it. The middle of the day is, therefore, relatively warm. At night the dry, still air permits rapid loss of heat from the earth and from the air nearest it, and the night is relatively cool.

The rapid warming of the lower air favors during the day a steady ascent and descent of warm and cool bodies of air with, at the height of about a mile, condensation of moisture from the ascending warm bodies into loose masses of white or gray clouds—cumulus clouds—that float a little way and then are dissipated, and that detract, by their coming and going, nothing from the general clearness.

The rapid cooling of the lower air lessens at night its power of rising, but puts it even more out of balance with its charge of moisture than if it had cooled during the day simply by rising. Often the moisture is deposited on the earth in the form of dew or of frost: frosts, in their season, are peculiarly an anticyclone product. As often, though, it is not deposited, but, still

retained in the lower air, condenses into fog. Summer and winter lowland fogs are a frequent feature of the otherwise fair anticyclone weather. In summer, owing to the intensity of the sunshine, they disappear wholly and quickly with the advance of day. But in winter, with the sunshine so much less strong and its period so much shorter, they often last the whole day through, and may, if the anticyclone proves a lingering one, last unbrokenly for a number of days.

The anticyclone's propensity to linger, added to its extreme clearness, works out into not only obstinate fogs, but also other effects that make its highest virtue seem for the moment only a fault. It becomes occasionally what is known as a "dead high," when it simply stands still and lets itself pile up. The effect for the time and in the region involved is much as if we had been robbed of a good part of our atmosphere. The sunshine pours down full strength in the middle of the day and makes everything overhot; and the heat pours out at night and leaves everything overcold. Much more often, though, what the anticyclone does by lingering is simply to prolong for about a week a period of truly fine weather, weather of

no more than seasonable warmth or coldness and with the air always fresh and dry.

A Country-wide Weather Procession

It is mainly between the Rocky Mountains and the Atlantic Ocean that the cyclones and the anticyclones exhibit their interplay on the large scale and with the constancy and conspicuousness that especially make the weather of the United States unique and notable. But they have also a large influence on the weather over all the country from the eastern side of the Rocky Mountains westward to the Pacific Ocean. It is a country that, with respect to weather, might be described as a group of petty kingdoms. Each abides in nearly complete independence of the others and refuses, more or less, to have any weather that is not of its own kind. The three great north and south mountain ranges—the Rockies, the Sierra Nevada and Cascade mountains, and the Coast Range—with the numerous cross-ranges, build up barriers that often shut foreign weather stoutly out and hold domestic weather tightly in. The result is that admirable specimens of about all of the well-marked types of weather that the earth

anywhere affords are to be found in this one region. Yet over it all, and in practically every recess of it, the same cyclonic alternations and progressions that come into the clearest dominance eastward are steadily at work.

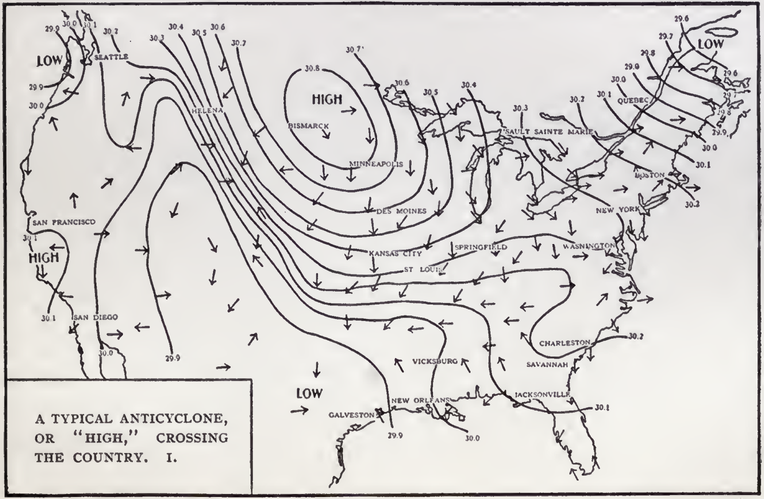
Many of the cyclones and anticyclones come, as we have seen, directly from the Pacific coast. Of these the larger number cross to the eastern side of the Rocky Mountains up near the Canadian border, but some cross in the middle latitudes and (of the cyclones, not of the anticyclones) some in the south. In many cases where they do not just show as coming from the Pacific coast it is pretty certain that they do come from there. And when, as is most frequently the case, they come in unmistakably from Canada, along the eastern side of the Rocky Mountains, they are often able to climb the mountains and spread out as freely and potently westward and southwestward as eastward and southeastward.

The cyclonic procession is, therefore, an affair of the entire country. There are no sections that need sulk and say that it may be a very curious and fine thing, but that it does not concern *them*. It concerns us all; and if it were as open to our sight as it is effective in our

lives we should never have to be urged to look at it. We should often become in our behavior like a body of school-children whom it was sought to keep in their seats and at their tasks just at the moment when the most spectacular part of a grand military parade was going by. We would get somehow our peep out-of-doors under the very nose of duty and authority. As the matter stands, however, the largest permission ever granted and the best point of view obtainable enables us to see only a little. That little, though, can prove immensely interesting. Perfectly bad weather may become positively pleasing when we have the habit of definitely looking at it and realizing to ourselves its place and proceeding in the whole movement by which all the weather comes.

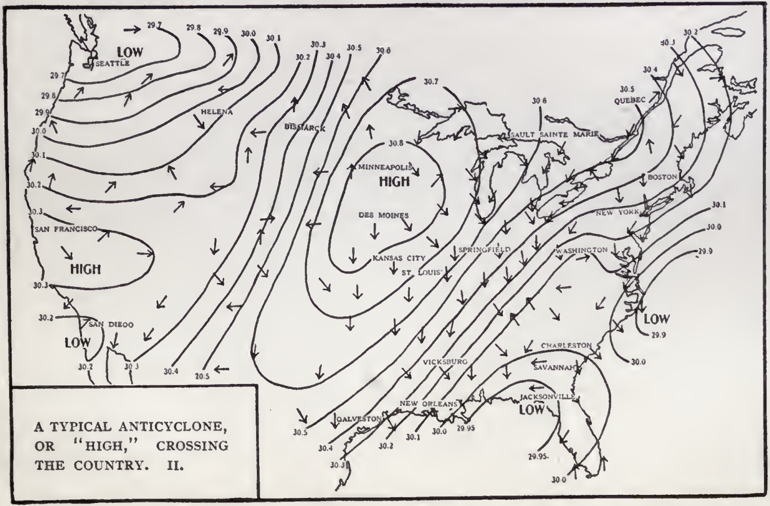
Some amends are made us for the scantness of our faculty for seeing the weather by the benevolence of the Weather Bureau. The daily weather report, read in the light of just a little knowledge of the subject, becomes quite a different affair from that for which commonly we have nothing but disparagement; and the daily weather map, for any one who has learned, as any one easily can learn, how to avail himself of it, makes a solid contribution to the steady

enjoyment of life. As portrayed in the daily map the weather gets the aspect and zest of a magnificent game, a game in which the highs and the lows are shrewdly and potently winning their way from ocean to ocean and are exhibiting, in a succession of grand plays, their own particular temperament and competency. The weather map has in it, therefore, something of a thrilling quality, and the dullness of a document is not in the least its character.



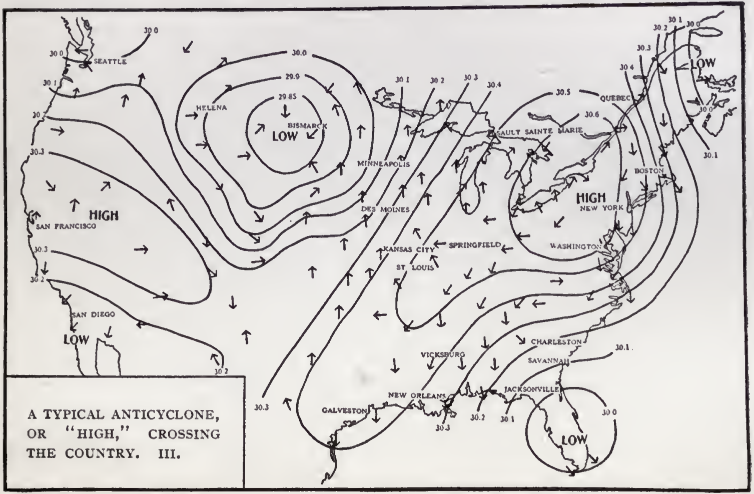
A TYPICAL ANTICYCLONE, OR "HIGH," CROSSING THE COUNTRY. I.

Morning of January 11, 1912. The anticyclone, or "high," is centered about Bismarck, North Dakota. Clear, cold weather prevails in the upper Mississippi and Missouri valleys. The succeeding maps show the "high's" position on succeeding mornings. The arrows point in the direction of the wind. The curved lines (isobars) connect places of equal air-pressure; the figures state the pressure in inches.



A TYPICAL ANTICYCLONE, OR "HIGH," CROSSING THE COUNTRY. II.

Morning of January 12, 1912. In twenty-four hours the center of the anticyclone, or "high," has moved from Bismarck, North Dakota, to the region of Des Moines, Iowa. The cold weather has spread over the entire Mississippi and Ohio valleys, amounting in most parts to a cold wave.



A TYPICAL ANTICYCLONE, OR "HIGH," CROSSING THE COUNTRY. III.

Morning of January 13, 1912. Another day's journey has carried the "high" from Iowa to the eastern Great Lakes. The entire eastern half of the country is now under a cold wave. But the cyclone, or "low," shown in the Northwest is establishing warmer weather in that region and will, in a day or two, displace the cold also in the East.

VIII

THE WEST INDIAN HURRICANE AND ITS PART IN OUR WEATHER

IN the work of controlling the daily variations of the weather the continental cyclones and anticyclones are called upon now and then, and in a very decisive manner, to share with another atmospheric organization, the West Indian hurricane.

Strict hurricanes never arise within the borders of the United States proper. They are exclusively of tropical origin, and they became an American product only by the annexation of Porto Rico and the Philippines, regions that are fairly fruitful in them. They find a natural breeding-ground in the latitudes where the comparatively cool trade-winds brush along or thrust into the equatorial belt of sluggish, overheated, overmoist air, known as the doldrums. They arise always over the ocean or over islands that are under strong oceanic con-

trol, never over the continents. They occur not only over the Atlantic Ocean, but also over the Indian Ocean and over the Pacific, off the southeast coast of China. In the East they are known as typhoons, and they occur both north and south of the equator. But over the Atlantic they occur only north of the equator, and they either arise or, at any rate, first come under official observation almost exclusively in the West Indies.

Of West Indian hurricanes important enough to be officially counted there were 121 in the thirty years 1880–1909. They came 8 in June, 5 in July, 28 in August, 40 in September and 40 in October. Hurricanes in any other than these five months are not unheard of in the West Indies, but they are extremely rare; and of the fact of their occurring with such uniformity there only in the latter half of summer and the early half of autumn, and of the further fact of their entire absence from the South Atlantic, a very interesting explanation has been offered.

What Confines the Hurricane to a Given Season and Course

Hurricanes are cyclones, and of a much more sharply defined, much tougher, and much more

forcible organization than continental cyclones. Their whirl, or gyration, like that of continental cyclones, is unfailingly from right to left, or contrary to the movement of the hands of a clock, in the northern hemisphere, and in the southern hemisphere as unfailingly from left to right, or with the movement of the hands of a clock. This proves them to be, at their organization, subject to strong deflection under the force of the earth's rotation.

Just at the equator this force is overmastering rather than deflective; it is there so strong that, so to say, it carries things all its own way. Hurricanes, in order to become cyclones, must, therefore, arise not too near the equator. The doldrums, on the edges of which they always do arise, have, it will be remembered, an annual progress north and south in their adhesion to the sun. They are at their farthest north in August and September; and since this is also the height of the season for the West Indian hurricanes, it is argued that only when the northern border of the Atlantic doldrums is most removed from the equator are atmospheric disturbances arising in that border apt to get just the right deflection to become cyclones.

The Atlantic doldrums lie throughout the year, however, more north of the equator than south of it. The long projection of Africa westward, just north of the equator, and of South America eastward, just south of it, so shapes the ocean currents that the water in the northern part of the South Atlantic is always relatively cool, and this coolness of the ocean surface keeps the doldrums always relatively far north. Their southern border at the southernmost migration lies in part directly on the equator and in no part more than a little south. It abounds in storms. But it is never far enough away from the equator, either north or south—just as, except about August and September, the northern border almost never is—for the storms to be deflected into cyclones. And this is the explanation offered of why there are no hurricanes over the South Atlantic and why those over the North Atlantic are mainly the occurrences of July, August, September, and October. It illustrates finely how land and sea and atmosphere, shone upon by the sun, work all together, and never apart, and not only for the moment, but through the months and the years, to produce the weather.

There is another condition, as curious as

those just explained, that affects the West Indian hurricanes perhaps in their season, and certainly in their place, of arising and in the courses over which they travel. Mention has already been made (page 20) of the fact that in the regions of tropical calm, about the thirtieth parallel of latitude, north and south, the general circulation of the atmosphere casts the air into semi-permanent belts of superior weight, or pressure, and that the northern belt of high pressure has an important part in our own weather. One way in which we experience its influence is in the control it exercises over the West Indian hurricanes. It is always much more strongly marked over the sea than over the land, and at times it practically disappears from the American continent. But it abides over the ocean, a well-defined body of air with an anticyclonic rotation, lying between our own southeastern coast and the northwest coast of Africa. Because of its clear definition and its constancy it has come to be known as the permanent North Atlantic anticyclone, or "high." Except that it is more extended, more enduring, and of greater potency, it does not differ materially from the oft-recurring continental anticyclones; and as they are thought

to be provokers of the continental cyclone, so is it thought to be much involved in the setting up of the West Indian hurricane. The hurricanes arise on or near its southern and southwestern border; and in the course of the hurricane season their ordinary place of arising shifts first eastward and then westward in apparently some correspondence with shifts of position shown by the anticyclone itself.

The Hurricane's Path and Speed

But the most open, most conspicuous effect of the North Atlantic anticyclone over the West Indian hurricanes is the compulsion it holds them under in their travels. The general circulation of the atmosphere in the region of their origin carries them at first northwestward. They cross the northern border of the tropics, and then the permanent eastward drift of the atmosphere in the north temperate zone lays hold of them and carries them northeastward. Very rarely do they fail to make in a general way this course. But with what directness they may make it, and also, in some measure, at what speed, seems to be determined for them largely by the North Atlantic anticyclone.

According as the anticyclone is more or less extended southward and westward are they driven westward before recurving and held afterward to more of a northward than northeastward progress.

Much the larger number manage to accomplish their entire course within the limits of the Atlantic proper. Starting at some point east or southeast of Porto Rico, they travel curvingly northwestward up to the latitude of Florida, and then, at a greater or a less distance east of the Florida coast, turn northward or northeastward. Many, however, are driven into the Gulf of Mexico; and when so driven, and having recurved, they are likely to invade the United States. Once in a while, though, the strong western extension of the Atlantic anticyclone prevents them from recurving at all, and they push into Mexico or southwestern Texas and are there dissipated. They are likeliest to be driven far west in the month of September, and it is in that month that we are apt to become most aware of them in the United States.

West Indian hurricanes vary greatly in their rate of travel. Some go with much more rapidity than do others; and they show different speeds in different parts of their course.

Up to the beginning of the recurve they move, it has been estimated, at an average rate of eighteen miles an hour. At the recurve they suffer a retardation. This is greater or less according as the angle of recurve is narrow or wide. Occasionally it amounts to a temporary stoppage, commonly to such a slowing up as makes the average rate of speed at the recurving-point six miles an hour.

Any check put upon West Indian hurricanes in their travel increases the intensity of their whole organization. They become more violent in their winds and their rain while the detention lasts; and after it is removed they steadily increase their speed. Their average rate, after recurving, is thirty-five miles an hour, or three miles an hour more than the average winter progress of our continental cyclones. They finish their course and disappear, as a rule, in the western Atlantic, somewhere between Florida and Newfoundland. But they occasionally reach Europe, preferably the region between Iceland and Norway.

The West Indian hurricane has a great place in romance and in history. It develops, oftener than not, an extreme violence, and since its course lies up and across one of the most-

traveled parts of all the ocean, it holds a great place in the records of sea disaster. Columbus had frightful encounters with it in more than one of his western voyages, and it greatly heightens the thrill and picturesqueness of the story of the discovery of America. In the stories of a host of subsequent navigators it figures as saliently. In spite of the absence of anything like systematic weather observation until quite recent times, it has been possible to compile a fairly detailed list of three hundred and fifty-five hurricanes arising in the West Indies between 1493 and 1855. In this list the later centuries naturally supply more items than do the earlier; yet fifty-four are of the period prior to 1700, and twenty-two are of that prior to 1600. So much of a record from times little given to leaving records shows something of the great impression that the West Indian hurricane has been making on seafaring men from the very beginning of their acquaintance with it.

It has made scarcely less impression on the sea romancers. They have found in it as sure a dependence for fluttering the hearts of fond readers as in the freebooters and buccaneers. The latter, so long since dead and forever vanished, must have been for some time back

a cooling material. And the hurricane as well, though it still survives in all of its old-time form and vigor, must be radiating some of its romance. It quite holds its own relatively among the great dangers of the sea. But under the substitution of steel steamships for wooden sailing-vessels and the installation of wireless telegraph and international weather observation it is becoming, like most of the others, daily more and more avoidable.

Constitution and Behavior of the Hurricane

It was through study of West Indian hurricanes that meteorologists first came to anything like a clear perception of the mechanism of atmospheric organizations. They exhibit this mechanism in its very highest perfection. Beside them the continental cyclone is a comparatively formless affair. They have never such wide extent as it reaches at its greatest. Their diameter may be as much as five hundred or six hundred miles, but is on an average only about three hundred. In height hurricanes are often as much as six miles, while the continental cyclone scarcely exceeds three miles. They are in form more nearly circular than it, and are in

all respects more evenly and compactly constituted.

A well-rounded, ever-renewing, swiftly rotating structure of wind and rain creates and maintains within itself, by its strong upward suction, a region of comparative calm. Because of the strength of the storm circle the quieter condition established at the center is much more marked in hurricanes than in the continental cyclone. But it is not, even in hurricanes, strictly a calm. The rains cease, the winds fall, the clouds disperse, and the sky becomes perfectly clear. But the waters remain troubled, and, under the cross-running of waves projected inward from all sides, may be even rougher than they are in the circle of storm. And the winds, although they fall, keep a velocity of from six to ten miles an hour, and are liable to break into gusts of a velocity of from eighty to ninety miles. To ships overtaken by a hurricane and surviving long enough to be embraced by the central calm it shows by contrast a sufficient light and graciousness to justify, no doubt, the name bestowed on it long ago, that of "the eye of the storm." But they gain in it, certainly, no true repose. Nor are they permitted to enjoy it long, for at its

largest it is not likely to be more than twenty or thirty miles across. Moreover, the danger of the passage out of it is apt to be greater than that of the passage in, for at the front of the hurricane the wind and rain increase gradually and then diminish gradually toward the central region, while at the rear they start up from that region with perilous abruptness.

Hurricanes, like continental cyclones, give forewarning of themselves by sending out aloft streamers of cirrus clouds. They do it, indeed, with a constancy and definiteness which the continental cyclones are not capable of. The streamers run out with about equal clearness from all quarters, but are more extended in the direction of the hurricane's progress. They have a difference of character, easily distinguished by practised observers, according to the size and intensity of the hurricane. They also mark this in the degree of their extension. They extend to a distance from the center of from three hundred to four hundred miles in hurricanes of small diameter and great violence, and in those of large diameter and less violence to a distance of from seven hundred to eight hundred miles.

A fair forewarning of hurricanes is given also

in the disturbance they raise in the waters of the sea. This disturbance is so widely propagated that it may announce them while they are yet two or three days' travel away. The form of it at its margin is a peculiar long swell, arising and continuing from no apparent cause.

In a hurricane, even more decisively than in a continental cyclone, the winds blow in toward the center from all quarters. They begin as a gentle breeze, but increase steadily in to the margin of the central calm, where on the front they have a gradual and on the rear an abrupt fall. When the winds have mounted to a mean velocity of from thirty-five to forty miles an hour rain begins. It comes at first in brief showers, during which the wind is split up into gusts of a velocity of from fifty-five to sixty miles an hour. Farther on the rain becomes continuous, but has rises and falls in its intensity. In correspondence with these the wind breaks up into great blasts and may show a force of one hundred, one hundred and ten, or even one hundred and twenty miles an hour. The rainfall is both more continuous and more copious in large storms than in small. In the smaller storms the rain area has an average extension of one hundred and fifty miles forward, but of only one

hundred miles backward. In the larger storms it is distributed more equally over the several quarters, and its average outward extension is about five hundred miles.

The Hurricane as It Operates in the United States

The most destructive storms experienced in the United States are West Indian hurricanes. About every year we are apt to have one come near enough to us to make a substantial impression at points on the Atlantic or Gulf coast, and somewhat inland. Every year along the coast, but more especially somewhat out from it, they are a menace to shipping throughout the hurricane season. Against the danger which they threaten there is now a large protection in the efficiency of the government weather-observation service. When ships are overtaken by a West Indian storm it is apt in these days to be through their own disregard of true and timely warnings. Such disregard is so frequent as to offer a standing example of human heedlessness. It often happens, though, that with all possible foresight and efficiency positions of safety cannot be reached. The West Indian hurricane is still, therefore, not entirely denied its high feasts of ships and seamen.

On meeting with land hurricanes are apt to suffer a rebuff. They sometimes dissipate entirely at the first encounter. The United States often get the benefit of this characteristic. One will come driving in toward our shores with the greatest violence, and the Weather Bureau will send out its sharpest warnings, and then we hear nothing more of it but that it has died out. A more common thing is for them to keep enough strength to cross the shore, but not enough to travel far or be much of a storm afterward. Most frequently, having landed, they tame down into ordinary continental cyclones, make a long northeasterly course, and, while remaining sturdy, are not really violent. They have no well-marked choice in their place of landing, but they come in somewhat oftener across the Gulf coast than across the south Atlantic coast, and rarely, if ever, across the north Atlantic coast.

Now and then one gets fully landed with its strength scarcely, if at all, diminished. Thereupon, unfailingly, a new chapter is added to our history of devastating storms. By a course often quite incalculable—perhaps from Texas straight northward and eastward to the Great

Lakes and the St. Lawrence valley, or straight eastward through the Gulf states and then northeastward through the Atlantic states; perhaps straight northward from Florida to the St. Lawrence valley; or perhaps straight northwestward from South Carolina to Minnesota—the hurricane drives fiercely across the country, wrecking structures, flooding farms and towns, and not infrequently destroying life.

Such visitations occur, not as often as once a year, but somewhat oftener than once in two years. They have come one a year for two years, for three years, and even for five, with a year intervening when there was none. A few times they have come two in a single year. There has been in their distribution no equality. September is the month of their greatest frequency and also of their greatest severity; after that, August; then October. Except in these three months severe hurricanes are not expected, nor more than the fewest of any sort. Yet of those notable enough in a period of twenty years to be given particular record one occurred in November, a month never rated as in the hurricane season.

Storms that Broke All Records

In September, 1875, a hurricane came up from somewhere in the region of Barbados, entered the Gulf of Mexico near Florida, crossed to Texas, and, settling with all its force on the town of Indianola, demolished all but the merest fraction of it and destroyed one hundred and seventy-six lives. Having finished with Indianola, it turned northeastward, its ferocity now considerably abated, crossed over to Virginia, and from there went out again to sea. This was classed at the time by the government Weather Bureau as the severest storm that had ever occurred in the United States "since the establishment of the weather service." But it was much exceeded in violence by one still in fresh memory, the Galveston storm of September, 1900.

This has been authoritatively pronounced "the severest and most destructive hurricane in the storm annals of the Western Hemisphere." It arose, like the other, in the region of Barbados. Traveling first westward and then northward, it nipped into the southwestern coast of Florida and wrecked a number of vessels. Then by a course a little north of

true west it crossed the Gulf of Mexico, and in crossing was encountered by the steamship *Louisiana*, which passed straight through the center of it, fought with gales blowing at more than a hundred miles an hour, and still survived. All the way the storm increased in strength steadily but rather slowly. It did not attain its greatest force until it neared Galveston, and only just there did it deal a truly great destruction. Six thousand people lost their lives by it, and property was destroyed to the value of twenty million dollars. From Galveston it passed, much modified, into Kansas and Nebraska, and then eastward across Iowa and Wisconsin. Suddenly recovering much of its strength, it swept over the Lakes and down the St. Lawrence valley, with large damage to property on both land and water. It occupied just a week with its devastating carnival along and within our borders.

Such an extreme performance as that of the Galveston storm is, of course, not to be classed as one of the regular features of our weather. We may believe, as well as hope, that it will not soon, if ever, be repeated. But it illustrates without any real exaggeration how truly an institution of our weather the West Indian

hurricane is. On occasions in the later summer and the earlier autumn the oceanic, or West Indian, cyclone steps in and simply takes the place of the continental cyclone. Except that it tends to be more violent, it does not differ from the latter in either its behavior or effect. In our experience of them we cannot tell one from the other. One as well as the other has always as a control the anticyclone, and the three together make the frame on which is shaped the general daily weather of the country.

IX

WINTER AND SUMMER WEATHER

INTERVALS of a day or of a few days each are not uncommon when over some part of the country no cyclone or anticyclone is in clear transit or of decisive influence. The weather during such intervals and in the regions affected might be defined as purely local. It takes more than usual the impression of strictly local conditions, and, except as influenced by these, is simply a matter of the air warming and cooling under the daily coming and going of the sun. But whether of this local type or of the more general, the cyclonic, it has always beneath and about it, as the ground and limit of its activity, the alternation of the seasons.

Strictly, there are but two seasons in any quarter of the world—that established by the sun's journey northward and that established by its journey southward. Even in the tem-

perate zones it is somewhat in disregard of the sun that the year is divided into four seasons. When, on the 21st of December, the sun, turning northward, begins its summer course, the first of what we know as the three winter months—December, January, and February—is not yet ended. The first of the three summer months—June, July, and August—is also not yet ended when, on June 21st, the sun turns southward and begins its winter course.

This disparity between our distribution of the seasons and the sun's actual position toward us is heightened by the fact that all of the sun's effects on the temperature come and go, not exactly with the sun, but always a little after it. This is true not only with reference to the year, but also with reference to the day. The warmest part of the day is not at noon, when the sun is directly overhead, but at about two o'clock of the afternoon; and the coldest part is not at midnight, when the sun is at its greatest daily departure, but at about four o'clock in the morning. Of the year the warmest part is the month of July, when the sun is already leaving us; and the coldest is the month of January, when the sun is already coming toward us.

There is no part of the United States in which

January is not the coldest month. There are individual weather stations whose records show now December and now February as colder than January. But they are scattered and do not represent what would be regarded as a section or region. January is the coldest month, not only in its average temperature, but also in its particular records. The absolutely coldest weather recorded in the course of a number of years is in practically every part of the country January weather. Every month has its record of abnormally cool or cold weather; but in any given region the record of no other month is as low as the record for January. Every month has its record of abnormally warm weather; but in any given region the warmest weather of January is colder than the warmest weather of any other month. The only concession to other months which January can be said to make in the quality of coldness is that at the greatest warmth of which it is capable it is not near as cold as the coldest of which some other months are capable. The lowest cold of February, for example, is in any one region much colder than the highest warmth of January.

While January holds its place as the leading

winter-weather month without any but the most local question, it has always a close competitor in February. The difference between them in general temperature is small, and the severest winter weather is apt to fall somewhere between the 20th of January and the 10th of February. Even when January proves unseasonably mild—as every few years, though each time much to our wonder, it does—it rarely fails toward the latter end to recover enough of its more familiar character to make us remark that we are getting some winter after all.

The severity at the end of January usually carries over into February. And even after the first third of February there is almost every year weather severe enough to make the month, to our feeling, quite as bad, on the whole, as January. This is partly because we have then had of winter quite enough, and our endurance begins to weaken. But in part it is also because in the latter part of February we get the first of those sudden, harsh changes of weather that always mark the departure of winter and exhibit the process to us in its true character, that of a breaking-up. About as many cyclones cross the country in February as in January,

and they come from all the points possible at any season, except from the West Indies, and so bend their courses as to weave over the country a closer network than in any other month.

The same complete pre-eminence shown by the month of January in coldness is shown by the month of July in warmth. July is the warmest month of the year in all parts of the country, not only in its ordinary temperature, but also in all its departures from the ordinary. In warmth, as in coldness, individual stations show some variation from the rule, but sections or regions show none. North and south, east and west, along the coasts and in the interior, July is almost invariably the warmest month, as January almost invariably is the coldest.

The Distribution of January Weather

There is, however, a very important difference between the distribution of the cold of January and that of the warmth of July among the different sections of the country. In the central section ordinary January weather is 55 degrees colder on the northern border than on the southern. In the northeast corner of

North Dakota and the northwest corner of Minnesota, which constitute the coldest region in all the country, the normal January temperature is zero. Follow from there a perfectly straight line south and the ordinary January weather grows steadily and rapidly warmer until, in the southernmost corner of Texas, the normal January temperature becomes 55 degrees above zero.

Start at any point in this line, whether in its northern, its middle, or its southern section, and go straight east, and again January weather grows warmer steadily, but now not rapidly, until on the Atlantic coast it shows as about 15 degrees warmer than at the point of starting. The normal January temperature for northern Maine is 15 degrees above zero, or 15 degrees warmer than that of the cold corners of North Dakota and Minnesota. For the southernmost part of Florida the normal is 70 degrees above zero, or 15 degrees warmer than that of southernmost Texas. The northern (or Maine) end of the Atlantic coast is, therefore, exactly as much colder in ordinary January weather than the southern (or Florida) end as northwest Minnesota is colder than southern Texas—namely, 55 degrees.

Going west from the central line, we find the distribution of January temperature considerably less regular than toward the east. Here also it grows gradually warmer in the direction of the sea. But the Rocky Mountains produce disturbance, and the increase of warmth seaward is not along the straight lines which so distinguish it in the east. Through the northern tier of states it is quite as regular as anywhere. Eastern Montana is 5 degrees warmer than the zero region in North Dakota; and western Montana is 15 degrees, Idaho 20 degrees, eastern Washington 25 degrees, and Washington at the Pacific coast 40 degrees warmer than that region. The increase westward is still fairly regular through South Dakota, Wyoming, southern Idaho, and Oregon. But through western Kansas, Colorado, Utah, and Nevada no increase westward is shown.

As it culminates at the seacoast the increase westward is quite a bit greater than the increase eastward. Southern South Carolina and northern Georgia have a normal January temperature of fifty degrees, the same as that of southern California, which is in the same latitude. But immediately north of this the Atlantic coast becomes 5 degrees colder for January than the

A MACKEREL SKY

The mackerel sky is made by cirrus clouds that form on a somewhat lower level than do the other kinds of cirrus. It is indicative of a change to stormy weather.

corresponding part of the Pacific coast; and the difference between them, latitude for latitude, grows steadily greater the farther north we go until, in contrast with a normal January temperature in Maine of only 15 degrees above zero, is found on the Pacific coast in the state of Washington a normal January temperature of 40 degrees above zero.

Instead of a range of 55 degrees shown on the Atlantic coast between the north end and the south end, the Pacific coast shows a range of only 10 degrees. From the southern boundary of California northward two-thirds of the way to Oregon the normal January temperature along the coast is continuously 50 degrees above zero. On from that point to a little north of the southern boundary of Oregon it is continuously 45 degrees. Then for the rest of the way to the Canadian border it is 40 degrees.

The reason for such evenly distributed midwinter warmth is not far to seek. The eastward movement of the general atmosphere brings a constant supply of warm air from the slow-cooling ocean in to the coast. It is only, though, a comparatively narrow border that enjoys this tempering influence. The air sweeps

on eastward under the general movement and soon begins to lose its warmth by contact with the winter-cooled mountains. It descends the eastern front of the Rocky Mountains with its gracious ocean quality about all gone. There it begins at once to mingle with air yet harsher that is pushing down from the great heaps of cold air which the winter has piled up over the continent in the north. The result is an increasing coldness of the air until the central line—the line from North Dakota to Texas—is reached. Here, however, air drawn from the southeast and south and a lessened coldness in the surface of the land begin to be effective, and there sets in that eastward warming up already mentioned as continuous from the central line to the Atlantic coast.

On the Atlantic coast, as on the Pacific, it is mainly the influence of the ocean that modifies the winter. But on the Atlantic side of the country air from the ocean has a much harder time getting in than on the Pacific side. The whole year through it has against it the eastward movement of the general atmosphere. Except during the warm part of the day in summer it has also against it a constant pressure seaward of air from over the land, due to the

greater coldness and density of such air in comparison with air from over the water.

Normally, along the Atlantic and Gulf coasts breezes from the sea are an affair only of the summer, and then only of the daytime. But the rule gets broken every few days by the passage of cyclones. These, as we have seen, are particularly frequent and particularly strong in winter, and, since by their rotating, upward draft they suck the air in from all directions, they draw in enough from the direction of the sea to modify somewhat the winter throughout the eastern and southeastern regions.

Commonly for the lessened severity of winter along the Atlantic coast all credit is given to the Gulf Stream—that current continually flowing out of the Gulf of Mexico between Florida and Cuba into the main body of the Atlantic and then northward and eastward, and keeping for a long distance a color and speed, as well as warmth, in clearly marked contrast with those of the surrounding ocean. But the persons whose opinion in such a matter is of any authority are pretty well agreed that, except somewhat along the shores of North and South Carolina, Georgia, and Florida, the Gulf Stream is with us of next to no effect. Down to the

middle of North Carolina the water that washes the Atlantic coast is a stream from the north, a cold stream, known as the Labrador current. Even, though, without the special warmth of the Gulf Stream to temper it any air that comes to us in winter from off the Atlantic will be warmer than the air coming then from the Rocky Mountains.

The Distribution of July Weather

In July, instead of a difference of 55 degrees, as in January, between the northern and the southern borders of the country in ordinary temperature, there is a difference of only 20 degrees. Between no one part of the country and any other is the difference more than this. Between the central region, extending from North Dakota to Texas and any of the country east of that, there is, latitude for latitude, almost no difference. At the north the normal July temperature is 65 degrees above zero; at the south it is from 81 to 82. The Atlantic coast is, though, on the whole, a little the cooler part.

Westward the Rocky Mountains again provoke, as in January, considerable irregularities.

Through southeastern Montana and southward through Wyoming, Colorado, and northern New Mexico, then northwestward through northern Utah and northern Nevada and, finally, through most of the length of California, a little back from the coast, the ordinary July temperature is 70 degrees above zero. And this is the same as that of South Dakota, southern Minnesota, Wisconsin, southern Michigan, central New York, and central New England. Just along the Pacific coast from Los Angeles north to the Canadian border the July normal is continuously 65 degrees above zero, and this is the same as that of the Maine coast. On the coast of North and South Carolina the normal is 80. The very hottest part of the country is the southeast corner of California and the southwest corner of Arizona, with an ordinary July temperature of 85 degrees above zero.

A difference in normal temperature of never more than twenty degrees between the several sections of a territory so vast and so multiform marks an evenness of atmospheric conditions that is extremely placating to the weather. In midsummer the weather tends always to be stable and even stagnant. It is cool or hot,

according to latitude, but is little subject to sharp changes. The average departures from normal temperature are not half as great as in midwinter. Areas of air of low pressure arise and traverse the country with little less frequency in summer than in winter. But they are for the most part mild organizations, scarcely deserving the name of cyclones and keeping in their slow travels pretty close to the northern border. Their most marked effect is to produce the local disparities of temperature that result in thunder-storms and tornadoes. Since these are always sharp and often destructive, the storminess of summer keeps us more in fear than the storminess of winter, but it is immeasurably less both in the time covered and in the total force raised and expended. Almost everywhere there is less cloudiness in summer than in winter, and the summer winds are much weaker than those of winter. Over the Western plains there is much more rainfall in summer than in winter, and in several other parts of the country there is in summer rather more than in winter. But in the rainiest part of all, the north Pacific coast, there is next to no rain in summer.

The Passage from Winter into Summer

After January in any part of the country each month is warmer than the month just before it up to and including July; and after July each month is colder than the month just before it up to and including January. In view of this fairly close parallel we might expect the two seasons of transition, spring and autumn, to be much alike. They are, in fact, though, quite different.

The passage from winter into summer is a much more halting and disturbed passage than that from summer into winter. The first of the spring months, March, hardly ever comes round that we don't deride and objurgate it for having got itself called a spring month. And April, as offering what we are willing to accept as spring, has with us scarcely better standing than March. We often mock also at what seem to be the unfounded pretensions of the first of the autumn months, September. But September is passive: its offense is nothing but a refusal to change. It stays as hot and humid as August. In March change, and harsh change, is the almost daily order. Bodies of very cold air from the north and bodies of warm air from

the south are in a constant battle. Now for a few days one controls the field, and now for a few days the other, according to the usual fortunes of war.

The nature of the conflict is shown rather clearly in the character and courses of the cyclones. These are about as numerous in March as in any of the winter months. But a somewhat less number of them than in January or February are from the southwest, a sign that spring begins to be already established there. Those from the northwest, on the other hand, are more frequent than in any other month, and, more unfailingly and farther than in any other month, they loop down into the south. This shows them to be under a very strong push from the cold masses of air on the lower borders of which they form. They are at the same time eagerly set upon by air of full spring warmth from the south. The contest between bodies of warm and bodies of cold air thus becomes extreme, and the main form of it is a conflict of winds. It continues with little or no abatement—often even with increase—as the cyclones, having turned northeastward, pursue their long course to the St. Lawrence valley. Poor March, in consequence,

has to bear the odium of being the squalliest, windiest month of all the year. We might, perhaps, have less discomfort in her presence than we commonly do if we remembered oftener what a truly magnificent business it is over which she presides.

The conflict so sharp in March continues through a good part of April. But it modifies from a succession of grim, boisterous, open fights into a sort of chuckling, impish guerilla warfare. There begins to be a pretty wide distribution of air that is both warmer and moister than the air of winter. It is, though, what might be called a spotty distribution—a little here and a little there—and offers fine ground for smart, little, unlooked-for outbursts of weather. The cyclones are fewer and keep to straighter courses, making fewer and shorter loops into the south, than in March or in any of the winter months. They still have considerably more strength than they show in summer, but are apt to provoke by their passage disturbances confined to relatively small areas. April has come to be known to us in its weather, therefore, as the embodiment of all fitfulness. Now fair, now cloudy, now warm and friendly, now cold and repellant, we yield it our love, but

never our confidence. It is known especially to us as the showery month.

The advance of spring is rather from the southwest than just from the south, and has something of an eastward as well as a northward course. It is not a steady advance, as the weather peculiar to March and April clearly shows. It is a succession of pushes forward only to be driven back that net each time some gain, until finally the whole field is won and placed under the full dominion of summer. Of the turns and time involved in the movement we can get some idea from the fact that May in central Massachusetts is, in its average warmth, six degrees colder than May in central Ohio, and just the same as March in central Alabama, and nearly the same as March in central Texas, and as February in southern Arizona. It is, on the whole, to New England and to the country around the upper part of the Great Lakes that spring comes last. Its lateness in the latter region is imputed, in part, to the slow warming-up of the water of the Lakes.

Winter and summer, once established, hold through a good part of their terms without much change. Between the several months of either season the difference in average tempera-

ture is small. This is the case in all parts of the country. While January is always the coldest month, it is, on an average, only from four to five degrees colder than December and only from one to two degrees colder than February. Likewise, July, while always the warmest month, is, on an average, only from four to five degrees warmer than June and only from one to two degrees warmer than August.

But between the months of transition, whether spring or autumn, the difference is much greater. On an average March is from eight to nine degrees warmer than February, April from twelve to thirteen degrees warmer than March, May from eleven to twelve degrees warmer than April, June from eight to nine degrees warmer than May. The average differences in autumn are practically the same. On an average September is colder than August by from eight to nine degrees, October colder than September by from eleven to twelve, November colder than October by from twelve to thirteen, and December colder than November by from eight to nine degrees.

While the changes of autumn closely offset, as in the nature of things they must, the changes of spring, the autumn transition is, in compari-

son with that of spring, a very equable affair. There is an increasing number of cyclones, with an increasing closeness of organization. But they travel pretty generally along the northern border and produce comparatively little rain. It is the season of West Indian hurricanes, and of those that come to us the harder ones show something of preference for the latter part of September. This, more than any sudden starting up of cyclones from the northwest, has fixed us in the habit of expecting about September 21st, when the sun in its journey south crosses the equator, what we call the equinoctial storm. The expectation is realized only just enough to keep it from year to year well alive. Such storms as come then or later, until near the end of November, are apt to be clean, straight-out affairs that, either of their presence or of their departure, leave us in no disgusting doubt. Of sharply variable, truly turbulent weather there is next to none until autumn is nearly or wholly past. Even the first good snowfall, which we who live within the snow-zone think it quite against nature not to have at or near Thanksgiving, often comes considerably after its date.

Pretty regularly the cyclones are followed by

anticyclones that keep the whole country suffused often for as much as a week or ten days at a time with cool, dry air that puts us all into the finest feeling. Under the exhilaration of this we think each year that we never knew before at that season such beautiful weather. But it comes just as fair and quickening practically every autumn. It was the definiteness and sure recurrence of it that long ago caused the period of it to be marked by a special name, that of Indian summer. Under the prevailing dryness dust from roads and plowed fields and from the breaking up of fallen foliage, along with smoke from forest fires, which are then most frequent, rises into the lower air and, in the absence of strong winds, lingers there. And this makes the familiar Indian-summer haze. Haze as deep and as enduring may occur at other times in the year; and even in Indian summer haze is not quite unfailing. But an Indian summer without it puts us always to the question whether, this year, we are not missing our Indian summer.

Spring, perhaps, has enjoyed more of the honors of poetry than autumn has. That is due in part to the fact that most of the earlier poetry was written in climates different from

ours, and we have taken over many of its ideas and phrases without too much thinking. But it is due in part also to the fact that spring, in spite of its fickleness—or, possibly, because of that—does fill the heart and the world with hope. Autumn does not exactly repress or expel hope, but it is at least somewhat sobering and subduing. The officials of the Weather Bureau ought not, though, to feel it so, for on account of its evenness and regularity they find it, they say, the easiest season of all the year in which to forecast the weather. That the public at large, however, has detected in their predictions for autumn a superior felicity over those of other seasons I rather doubt. In any craft it is only the devotees who know its nicer joys.

X

HOT AND COLD WAVES, AND OTHER EXCESSES OF THE SEASONS

THE seasons maintain, if not through the year, certainly through the years, a notable fidelity to their times, and as notable a uniformity in their effects. But, like all nature, human and other, they reward their virtue now and then by running into excesses. Of these, most familiar, perhaps, are the cold waves of winter and the hot waves of summer. In neither the one nor the other is there any departure from the ordinary course of things, but only a pursuit of that course with for the moment more than ordinary zeal. Cyclones and anticyclones are still the immediate masters of the weather even when it breaks into these seemingly freakish forms.

The Cold Wave

A cyclone not essentially different from those that are all the time forming and moving off

across the country gets established somewhere along the eastern front of the Rocky Mountains. Close behind it is an anticyclone of extreme coldness. This comes oftenest in through Montana, and can usually be traced back to some point considerably north of there. Most frequently it attracts observation by its special quality first in the region of the Klondike, and has sometimes been under surveillance for two or three weeks before it crosses our border. How far its exceptional coldness is due simply to the northerliness of its place of starting, and how far to a particular state of the higher atmosphere from which much of the air it dispenses is drawn down, remains quite undetermined. We can say with certainty of it only that here it is, and that it is extraordinarily cold.

The cyclone, choosing one or another of the wonted paths, goes its way. It draws into the front of it, like any other cyclone, relatively warm air from the east and south. But at the rear it draws into it, or rather has driven into it, from the close-following anticyclone air much colder than is usual even from the cold quarter. Thus there is built up between its warm southeast and its cold northwest quarter a difference of temperature much beyond the

ordinary. The difference may amount to more than forty degrees. It is bestowed without reserve upon all the localities that the cyclone visits. To-day they will have mild, warming breezes from the east or south, with, probably, rain. To-morrow the rain, perhaps, has turned into snow and the breezes have become a west or northwest blast, driving cold into the very marrow of man and beast.

If the cyclone bends its course far into the south the cold wave spreads over the whole country east of the Rocky Mountains. But if it keeps well up in its course the northern half of the country may experience a perfectly cruel change of which the southern half gets scarcely a touch. West of the Rocky Mountains the effect of cold waves coming in through Montana is less clear and positive than to the east. But they do often have a western spread. The great diversity of altitude and exposure throughout the Plateau and Pacific slope region makes abrupt changes of temperature more common there than in any other part of the country, but also more confined and local. Yet many of the sharp descents of cold come unmistakably from the east and north. Occasionally they traverse the entire region, running

even to the southern border of California and producing unquestionable ice at San Diego, where the ordinary winter temperature is twenty-three degrees above freezing. The very rarity of such invasions makes them extremely damaging.

There are winter anticyclones coming in through Washington and Oregon from off the Pacific. At starting they are relatively warm and also moist. They become colder in crossing the mountains, and shed their excess of moisture, often in the form of snow. They sometimes produce snow not only on the western, but also on the eastern slope. Occasionally one of them, having passed the mountains, encounters a trough of warm, moist air lying stretched out northeast and southwest between Arizona and the Great Lakes and cuts it quite in two. The southern fragment thereupon rounds up into an active cyclone; and under the further career of it and the anticyclone heavy snows and considerably colder weather are produced over most of the country eastward.

Very sudden cold waves are brought to us only on the western skirts of a cyclone. If in addition to being very sudden they are also very strong, there is sure to be close behind the

cyclone an anticyclone of extreme coldness. But those quite as sudden, though perhaps never so strong, may arise from a cyclone's drawing into it, not abnormally cold air at the rear, but abnormally warm air at the front. In such a case, the eastern quarters being excessively warm, the western quarters need not be excessively cold to make the change of temperature under the cyclone's passage still sharp.

Cold waves coming in either of these two ways are apt to be brief. With any one of them three days will usually see it all come and gone. They are also quite sure to be attended by high winds. It is under the advance of the severer ones that we get that for which we have coined the expressive name of blizzard. Under the ruthless drive of the wind a storm beginning perhaps in rain, but turning first into sleet and then into snow, becomes so bewildering and exhausting that often men and animals simply sink down before it and perish in the magically risen drifts. This feature of it is what makes the cold wave especially harmful throughout the northern half of the region between the Mississippi River and the Rocky Mountains.

A cold anticyclone often produces a cold wave more by its presence than by its progress. The cold wave is established, not at the point where the anticyclone is pouring its cold air into a preceding cyclone, but in the central region of the anticyclone and westward from there. The anticyclone, being itself very cold, simply imparts its temperature to the country lying just under it. A cold wave of this kind comes, as a rule, without high wind and gradually. It is never so shocking as the other kind, but it may, by its steady piling up, become much colder. And it may, if the anticyclone is of slow movement, as anticyclones often are, continue over a given region for more than a week. In that case it rather exceeds the limits of a cold wave and becomes more properly a cold term.

Under cold waves of this kind there may be abundant discomfort, but there is apt to be no great damage. A curious and interesting feature of them is that the layer of clear, cold air which they spread abroad is comparatively thin. This is indicated in such observations as that, for example, when in the region of Helena, Montana, the temperature was from twenty-five to thirty degrees below zero, on levels just

beside it, but about three thousand feet higher, the temperature was above freezing.

Changes of the kind that we know as cold waves may occur at any season. But it is only in the winter half of the year that they carry the temperature from warmth down into positive coldness. To give the phrase a working quality the Weather Bureau has, so to say, "standardized" the cold wave. The standard varies somewhat according to time and place. Along the Gulf coast there must be to constitute a cold wave a fall in temperature within a period of twenty-four hours of at least sixteen degrees; and in other districts there must be a fall of at least twenty degrees. In the colder regions the fall must be also to at least zero in the colder months, December, January, and February. But in November and March a fall to ten above zero will suffice. Along the Gulf and in Florida a fall at any time to only the freezing-point (thirty-two degrees) is enough.

Of cold waves that fulfil these requirements there are, on an average, three or four a year. They are about as likely to occur in one as in another of the five months to which they are confined, except that they are rarest in Novem-

ber; and they are no more likely—are, perhaps, less likely—to occur in prevailingly cold winters than in winters marked by considerable stretches of mildness. The fall of temperature they effect is sometimes tremendous—more than fifty degrees within a period of twenty-four hours.

The Hot Wave

The hot wave is to the summer season exactly what the cold wave is to the winter—a brief, strong, wide-sweeping increase of the season's natural quality. As in its quality, though, so in the manner of its production, it is the direct opposite of the cold wave. While the latter is always bred and nourished by a cold anticyclone from the northwest, the hot wave gets its birth and substance always from a hot anticyclone in the southeast. The hot anticyclone is, however, deemed to be, not a distinct organization in itself, but a part of that belt of air of high pressure already described as lying, with more or less permanence, across the Atlantic Ocean, and as having much to do with the rise and behavior of West Indian hurricanes.

At a time when this belt chances to be rather farther and more strongly projected than ordi-

narily over the Southeastern states there may arise in the northwest an area of air of low pressure which has close behind it no definite anticyclone to round it up and drive it forward. Itself scantly defined and sluggish, it lingers in one place. It is still, though, of low enough pressure to be an attractive object to the air of high pressure in the southeast. This begins, therefore, to stream north and west. It is hot at starting, and it cools little in its northward progress, partly because it travels fast and partly because everywhere the land over which it flows is at full, or nearly full, summer warmth. It thus establishes in all the country it invades the hottest kind of weather. Its effect is apt to be severest through the Mississippi and the Ohio valleys; but it is often severe enough to be rated that of a hot wave everywhere between the Rocky Mountains and the Atlantic Ocean.

Just along the Atlantic coast the effect is usually, though not unfailingly, much modified by the sea-breezes prevalent through the middle of the day in summer. To the Pacific coast the strict hot wave never quite reaches, though periods of a day or two of abnormal heat sometimes occur there. It may extend into and even across the Rocky Mountains. But the

great elevation of the mountain and plateau regions insures to them a rapid radiation and cooling off at night, and the hotness of the nights as well as of the days enters into the definition of a true hot wave.

It is always, indeed, directly in proportion as hot nights are combined with hot days that hot waves prove disastrous. For a number of days successively the heat may mount during the day to extraordinary heights; but if the intervening nights turn comparatively cool the number of prostrations and deaths will be much less than under a considerably lower temperature continuing with scant abatement through the day and night. Thus any situation that peculiarly favors cooling off at night has a clear advantage during the prevalence of a hot wave. It is also an advantage to be inured to heat. The same degree of it that would cause great suffering to the people of the North imposes nothing more than discomfort on the people of the South.

The South, however, is the region in which hot waves provoke least change. Since they start there, the temperatures they carry with them are but those already more or less prevalent there. The severity of them tends to

become greater and greater as they proceed northward, until finally some line is crossed where they themselves begin decidedly to cool. Thus, in one of the most fatal hot waves of which we have official record no increase of temperature worth mentioning occurred at, for example, either Jacksonville, Florida; Charleston, South Carolina; or New Orleans. But at St. Louis, Chicago, New York, and Boston the temperature not only had very strong individual rises, but also maintained through a number of days an average anywhere from thirteen to seventeen degrees above normal. The South, therefore, is the region to which we should repair in order to escape not only cold waves, but also hot ones. Its own suffering is, on the whole, more from the former than from the latter.

The conditions that are necessary to a hot wave may arise at any season. But they arise with more frequency and in greater strength in summer than in winter; and it is, of course, only in summer that in our latitude air poured forth from any quarter is truly hot. To provoke a hot wave there must be somewhat of a pause and feebleness in the movement eastward of cyclones and anticyclones from the north-

west. This in summer is rather the ordinary character of the movement, but in winter is exceptional in it. For strict hot waves June, July, August, and September are the only months. Of the four June is the least liable to them, July most; but August and September have a liability not much less than that of July. Those of July and August are apt to be severer than those of September and June because they are apt to be both hotter and dryer.

Beyond the very loose one of confinement to the hotter months hot waves exhibit no regularity. They may come strong or weak, and in close succession or far apart. There is hardly, if ever, a summer without one, and there may be in a single summer a number of them—say, four or five. They are not necessarily confined to summers that are prevailingly hot, nor are they necessarily more frequent in such summers. The highest absolute heat produced by them is apt not to come until a day or two after the arrival of the wave itself.

Usually a hot wave is dissipated by the organization and movement eastward of a cyclone of some strength, followed by an anticyclone. But it may simply waste away under a shift or withdrawal eastward of the Atlantic belt

of high pressure out of which it is fed. The stagnation of the ordinary atmospheric exchanges in which alone it can arise is apt, though, to be itself prolonged. Under such favoring the hot wave exceeds its ordinary limit, which is three or four days, and lengthens out into what we know as a heated term. And since in the weather any continued warming up is bound to become also a drying up, the lengthening of a hot wave into a heated term is nearly always productive of a drought. It is, therefore, more under the heated term than under the mere hot wave that we discover of what severities summer—somehow always more amiable than winter to us in its general associations—is really capable.

Mild Seasons and Hard Seasons

Hot waves and cold waves, even when they stretch out into terms, are episodes. But the seasons often indulge in excesses that are season long. There is never any that does not have its irregularities, its abnormalities; and within any period of a few years there is sure to come one, either a summer or a winter, so constant in them that its whole character is

abnormal. It shows, in comparison with an ordinary season, as either colder or warmer, and at the same time as either wetter or dryer. A hot summer and a cold winter are also dry. A cold summer and a warm winter, on the other hand, are also wet.

They come with no discernible regularity, these entire seasons of unusual warmth or coldness. Mainly out of personal memory of them, which is apt to be vague and inexact, we have framed various rules for them; and these we cite, if not with great confidence, certainly with great contentment. But they are quite as often contradicted as confirmed by the actual count. A warm winter, for example, may be followed by a cool summer, and a hot summer by a cold winter. This happens, though, no oftener than it fails to happen. Also it often happens that of two extreme winters or of two extreme summers, whether hot or cold, one comes the very next year after the other. All that we can safely expect in the matter is that one or another of the several kinds of extreme season will occur every few years, and that there will be no very long succession of what to us will seem quite ordinary seasons.

It is always grateful to us to think that the

severity of one season will be made up to us by a special mildness in one soon to follow. And this occurs frequently enough quite to justify us in entertaining it at least as a hope, if not as an expectation. There is, undoubtedly, an equalization of the extremes of weather. But it is not accomplished too promptly or too openly. We can detect it only in proportion as we increase the number of years through which we search for it. Long periods offer clearer proof of it than do short ones.

An extreme season is not, when it occurs, always well marked in all parts of the country. Sometimes when very pronounced in one part it is little or not at all apparent in another. Usually, whatever its kind, its general strength is greatest through the central region between the Rocky Mountains and the Appalachians. Its highest absolute degree may not be attained there, but ordinarily its highest average will be. It may, though, show also within this region considerable differences between different parts, and especially between North and South.

Often a season extreme with us proves, within our latitude, extreme in the same way nearly or quite round the world. This fact emphasizes what, indeed, the whole character of

extreme seasons indicates—that they are not mere casual or local departures from ordinary weather. They must, it would seem, originate in some departure of the atmosphere itself from its usual organization and movements. Perhaps the most eager pursuit at the present time of the many faithful students and observers who are perfecting the science of the weather is to find out just what of this kind does occur and what are the causes of it. Almost any day some discovery in just this direction may occur that will be of incalculable value. For with a fuller knowledge of the variations of the atmosphere at large, forecasts of the weather, not simply for a few days, but for the seasons and the year, and even for a series of years, might very well become possible. To expect some such thing is not in the least fantastic, but quite within probability.

Unexplained Variations of the Atmosphere

The fact that there are such variations and something of their character are already known. For instance, the movement of the main body of the atmosphere in our latitude never ceases to be eastward, but it is known to change its

speed. One time it is very rapid, and another time very slow. This associates itself inevitably with another thing that has been observed: that the whole procession of cyclones and anticyclones, out of which we get more immediately our ordinary changes of weather, has sometimes sudden changes in its speed and force, and that these changes may appear almost simultaneously in the United States, Europe, and Asia. Then it is known that at any one time of the year the great areas of air, of either high or low pressure, that build up half permanently over the oceans and the continents may show important differences in their location and in their strength, and that these differences have much to do with the weather.

Our own summer weather, as is shown, for example, in hot waves and West Indian hurricanes, has dependence of the clearest kind on the particular place and intensity of the Atlantic area of high pressure. And it is believed that our winter weather varies more or less in answer to the lay and strength of the great area of air of high pressure that forms in winter over northern Asia.

But while the occurrence and something of the features of the more fundamental atmos-

pheric variations are already known, the cause of them remains still very much hidden. In the eager search for it going on the object first and most questioned is, naturally, the sun. The sun, indeed, is just now as if it were a trust under investigation by a congressional commission—an investigation without, though, let us hope, any politics in it. The sun itself shows, on the very face of it, that it changes its condition. It offers an especially conspicuous mark of this in the sun spots—those areas of profound disturbance that, appearing on the surface of the sun, gradually increase in number and in size through a period of something more than five years, then through an equal period gradually diminish, and then for about the sum of these two periods, or about eleven years, are entirely invisible, at least to human observation. One can hardly believe that a variation so constant and so great as this apparently is does not have some effect on the weather, seeing that the energy that makes the weather comes from the sun. Hence, the professional effort to find out and the popular desire to know are both eager.

They are also fairly eager in another inquiry: whether of the energy that makes the weather

all really does come from the sun, and whether at least some small fraction of it may not be from, say, the moon or the planets or even from the stars. We can none of us give up, though we may yield so far as to somewhat veil, our inherited belief that the moon has much to do with the weather. But scientific investigation finds between the two no relation or connection that is appreciable. It also finds none between the weather and either the planets or the stars. There is a sense, though, with regard to the moon that some connection may yet appear. There is also this sense, but less strong, with regard to the planets, and even — though here manifestly feeble — with regard to the stars.

As to changes of weather due to variations in the amount of energy received on the earth from the sun, the most authoritative opinion is that, while recent observation and study have brought out much that is suggestive of such changes, there is as yet no clear proof of their occurrence. But the most conservative masters of the subject allow that it may have, at almost any time, a sudden and quite decisive unfoldment.

Does the Nature of the Seasons Change?

Almost any one who has been exposed to the weather years enough to begin to cherish memories of it, is likely to have an impression that the seasons are making a permanent change. The impression is due, however, more to the preciousness of the memories than to their perfection. If our memories of the weather were more comprehensive, the sense of radical change in it would be less common. Of this I myself once had a peculiar and very interesting proof.

There lived in a town where I was conducting a newspaper a woman of one of those abnormal memories that carry, without once dropping, anything and all that is handed them. She was eighty years old, had lived all her life in that town, and, having no special employment for her memory, had laid up in it whatever chanced to catch her attention. She remembered dates of birth, of marriage, and of death, and incidents of the ordinary life of the town in marvelous profusion. She was an authority to people who had had part in them on occurrences in which she herself had had none. But it was in the matter of the weather that her

opulence and exactness of memory most shone. This suggested that a review by her of the weather as she herself had experienced it would make a good article for the newspaper.

The article was prepared, and proved to be, what articles as a rule seem so bound not to be, better even than the editor had anticipated. It was, indeed, wonderful. It recalled, wholly from memory, the weather of fifty years, not only year by year, but season by season, and even in many of its sallies on particular days with, in most instances, the exact date of the day. It was interesting primarily, of course, as a feat of memory; but it was scarcely less so as a story. To me, who was already acquiring from my own loose recollections the common belief that the seasons were no longer what they had been, the most impressive thing finally in the review was its clear indication that the seasons, in spite of their freaks and excesses, remained entirely true to themselves, that fundamentally they disclosed no change.

And this, in effect, is the conclusion also of all scientific inquiries into the matter. Such inquiries have been made from time to time with the utmost care, and the conclusion, drawn from comparison and analysis of author-

itative weather records for the full periods through which such records have been kept, is that the seasons maintain an average practically invariable of strength, deportment, and effect. But notwithstanding this nobody can believe, in view of the known mutability of the entire universe, that fundamentally the seasons do not change. They must change; they cannot possibly save themselves from change. But the change, apparently, is of that grand, slow order which the universe is fond of, and which, being hidden from ordinary perception, is for ordinary human life and endeavor practically non-existent.

XI

THE WINDS

ALL over the country the natural tendency of the wind is to blow from west to east. It is a tendency much interfered with by the irregularities of the land, and yet more by the frequent breaking of the air, under differences of temperature, into those persistent whirls which we know as cyclones and anticyclones. But in spite of all hindrances much the largest part of the wind in the course of the year is from the west.

The point in the west from which it comes most is the northwest. This, however, is more its habit in the winter half of the year than in the summer half. The lessening pressure of air down from the north, under the tempering advance of spring and summer, and the increasing pressure of air into the country, especially into the southern half, from the relatively cool oceans and Gulf produce in summer some-

what of a shift of the entire wind system. Under this, winds from points in the west diminish and winds from points in the east increase, particularly southeast winds. Those from the west still remain, on the whole, the prevailing ones; but they show the strengthened pressure of the air from the south in that now more of them are from the southwest and fewer from the northwest than in winter.

This gives the southwest winds an approach in quantity to the northwest winds, but only an approach. The northwest remain for the year considerably the larger part of all the winds from western points. Winds directly from the west are much fewer than those from either the northwest or the southwest. They are much more frequent, however, than winds directly from the east, which are the fewest of all recorded.

The Winds in the Different Parts of the Country

Naturally, in its disposition to blow from west to east whenever it can the wind meets with more obstruction in some parts of the country than in others. The conditions espe-

CUMULUS, OR HEAPED-UP, CLOUDS BROKEN AND SCATTERED BY THE WIND

All kinds of clouds often break up and acquire new aspects under the force of strong winds. But cumulus clouds, piling up high and well-defined as they do in their first formation, show it rather more clearly than other kinds when the wind tears them to pieces. Thus broken up they are known as fracto-cumulus.

cially favor it just along the Pacific coast. The eastward movement of the general atmosphere, constant throughout the year, combines in summer with a draft created by the superior heat of the land, and the air comes in largely from the ocean. It suffers little disturbance until it reaches the mountains.

From a half to three-quarters of the entire wind of the year on the Pacific coast is from some part of the west. The proportion is less on the north coast than on the south, and is most on the middle coast, in the region of San Francisco. It is there from seventy to seventy-five per cent., which is considerably larger than the proportion shown in any other part of the country. Along most of the coast it is the northwest winds that prevail; but at San Francisco and again at Los Angeles it is the west wind. No other points in the country show as large a proportion of direct west wind as these. There are months during which the prevailing winds at certain points are from either the north or the south, or else from northeast or southeast. But even at such points the west and westerly winds remain the prevailing ones for the year.

In the plateau and mountain regions, from

the northern border of Idaho and Montana to the southern border of Arizona and New Mexico, winds from some part of the west are still in much the larger proportion. But there is about an even division between those from the northwest and those from the southwest, some districts having the one and some the other as the prevailing wind of the year. Two districts here show what is not shown anywhere along the Pacific coast—prevailing winds for the year from some part of the east. They are the districts of Salt Lake and Santa Fé, in both of which the prevailing winds are southeast. In most of the districts here there is but slight change from month to month, and in several what is the prevailing wind for the year is also the prevailing one for every month in the year. This is the case at Denver, Colorado, where the prevailing wind is from the south; and also at Helena, Montana, where it is from the southwest.

From the Rocky Mountains eastward, through nearly all the central regions to the Appalachians, winds from some part of the west still remain the prevailing ones of the year. But they are less markedly so here than in any other of the large divisions of the country;

and there is here a more pronounced variation between winter and summer of wind directions than in any other division. Through the Dakotas, Minnesota, Wisconsin, Michigan, northern Illinois, Iowa, Nebraska, Kansas, and Missouri the largest proportion of the wind movement of the year is from the northwest. But under the falling away of northwest winds in summer southwest winds become in various parts the prevailing ones of summer, and enough so in some to show as the prevailing ones for the entire year. The spring and summer shift introduces also southeast winds; and these too, by virtue of this admission, are able to show in a few districts as the prevailing ones of the year.

Through southern Illinois, Indiana, Ohio, Kentucky, and Tennessee there is more of southwest wind than of northwest; but between them they give the general movement from west to east a clear predominance for the year. This is, though, so far modified in summer that south wind in some districts and southeast wind in others become prevailing for certain months, and in a few instances for the whole year.

Thus through both the north and the middle of the central regions the westerly winds keep their ascendancy for the year, though much

displaced in summer by the southerly and easterly. But in the part comprising Arkansas, Mississippi, Louisiana, and Texas they quite lose it. Here the prevailing wind for the year, while different in different districts, is almost invariably from either the south or the southeast. Northwest winds prevail through the winter at some points; but in most districts they attain to prevalence for not a single month in the year.

Such losses as the winds from western points suffer in the central regions they quite recover in the regions of the Atlantic coast. Through New England, the state of New York, Pennsylvania, New Jersey, Delaware, Maryland, and Virginia the prevailing wind for the year is, speaking generally, everywhere the northwest wind. It gives place through the summer to the southwest wind, and that is the prevailing one for each of the three summer months. Such departures from this distribution as occur are confined to individual districts and make but a small exception to the rule.

The southwest winds supersede the northwest through North and South Carolina, and become the prevailing ones for the year. But they yield the prevalence to northeast winds

through the autumn months and December. This distribution appears also in Florida; with, though, an extension of the term of the northeast winds, so that these are the prevailing ones for the year and the southwest predominate only in summer. The eminence thus shown in the northeast winds is peculiar to that region; it appears nowhere else in the country. It extends somewhat into Georgia, but in northern Georgia the northwest winds are again in almost exclusive prevalence; and the sum of the matter for the south Atlantic states, as for the middle and the north Atlantic, is a strong predominance for the year of winds from some part of the west.

Sea-breezes and Cyclonic Winds

And this is just the opposite of what one might have guessed, in view of the great account taken along the Atlantic coast, in speech and in feeling, of two features of the wind movement there: the easterly gale and the sea-breeze, which, of course, is also easterly. It is the harshness of the one and the graciousness of the other, more than the actual frequency of either, that makes them impressive.

The strict sea-breeze is but a slender, short-

lived affair. It arises only in summer, with some laps into the later spring and the earlier autumn, and lasts each day only from the middle of the forenoon until toward evening—that is, during the hours when, under the daily mount of the sun, the surface of the land is efficiently hotter than that of a narrow strip of the water bordering. It begins at a somewhat less distance out than it extends inland, and its extension inland is, on an average, not more than twenty-five or thirty miles. To the general Atlantic coast region more tempering, probably, than the sea-breeze are the bodies of air so frequently drawn in from the sea under the advance of cyclones. It is just bodies of air so drawn in that, making their approach with extreme eagerness, raise the easterly gale; and their easterly movement is apt to be more or less offset in each instance by the westerly winds that always attend the cyclone's departure.

Nothing in all the wind distribution is of greater interest than that in the central regions, while the west and westerly winds maintain a clear predominance, they are more nearly equaled there by winds from other quarters than in any other part of the country. It is in

the central regions that the appearance of cyclones and anticyclones is most constant and that they are least disturbed or perverted in their movements and effects. The abundance there of easterly and south winds, in comparison with westerly, is a striking mark, therefore, of how truly organizations these areas of air are, and also how effective in the nature and office imputed to them—that of creating, the one toward them, the other from them, movements of air on all sides. The fact that the westerly winds still remain the more frequent only adds sharpness to the exhibition, since it shows that in the lulls which we know to occur in the general cyclone and anticyclone movement the air simply settles down into its normal direction of from west to east. And considering over what a great width of country this all so clearly appears, we get from it a better sense than, perhaps, from anything else of the magnitude and at the same time of the precision of our system of weather.

The Velocity of the Wind

The general wind velocity has on land—but not on the open sea—a daily increase and de-

cline like that shown in sea-breezes. It begins to quicken early in the morning as soon as the lower layers of air begin to feel the heat of the sun. It continues to quicken until two or three o'clock in the afternoon, and then begins to decline. The time of greatest stillness is in the after part of the night. This daily variation is, however, lost in the midst of a storm.

The general strength of the winds is much greater through the winter half of the year than through the summer half; but the months in which it is greatest are spring months—first March and then April. The two months in which it is least are July and August. Of positive calm there is in most places scarcely enough in the course of the year to make a record. At such places as it does make a record it is about as much a winter product as a summer.

The winds became classified long ago according to their strength, under simply the prompting of human feeling. The weather authorities have adopted this classification, merely adding the measures needful for their nicer uses. A light wind, for instance, is what we have always known it to be. But according to one well-approved scale it must be of a velocity not ex-

ceeding three miles an hour. A velocity of anything more than that up to and including five miles an hour makes a gentle wind; and this, according to a useful instruction issued for the general guidance, "moves leaves of trees." The other kinds and their velocities and traits are: Fresh—6 to 14 miles an hour: "moves small branches of trees." Brisk—15 to 24 miles an hour: "good sailing breeze and makes whitecaps." High—25 to 39 miles an hour: "sways trees and breaks small branches." Gale—40 to 59 miles an hour: "dangerous for sailing-vessels." Storm—60 to 79 miles an hour: "prostrates exposed trees and frail houses." And, last but not least, hurricane—80 or more miles an hour: "prostrates everything." The final characterization seems a little strong, in view of the fact that sky-scrapers in New York withstand winds of more than a hundred miles an hour. But it was intended, no doubt, especially for a warning at sea, where, of course, the situation is always delicate.

The parts of the country in which the winds show greatest strength are, first, the two coasts, the Atlantic and the Pacific, on the one from South Carolina northward and on the other

from San Francisco northward; and, then, along the shores of the Great Lakes and in front of the Rocky Mountains, over the Great Plains. Around the Lakes they are much stronger on the south shores than on the north; and, clearly, what gives them their special intensity is the comparative smoothness of the surface over which they travel. And it is mainly owing to a surface more nearly like that of a great body of water than is shown in any other great stretch of land in the country that the winds are peculiarly strong over the Plains.

But along the coasts, in addition to any special strength they may get through coming largely from off the water, they are apt to get both a greater velocity and a greater violence from the sharp differences of temperature often arising there between land and water and the sharp obstructions presented by the land. They especially rage about abrupt projections of land, like Point Reyes, on the Pacific coast, and Cape Hatteras, on the Atlantic.

The prevalence of high winds depends, in most parts of the country, mainly on the frequency and strength of cyclones. The contour of the land and even its growths—its woodedness or treelessness — make great differences

for different places. But, leaving these out of the account, the liability of particular points or districts to such winds corresponds rather closely to their situation with reference to the ordinary cyclone tracks. Some of the more aptly situated have achieved even in the winds of the rarity of gales—winds of forty miles or more an hour—an imposing record. At Amarillo, Texas, during a period of ten years there were gales on 756 days—an average of seventy-five days in the year. The record at Huron, South Dakota, during the same period, while much below this, was still not mean—357 days with gales. At both places the month that had the largest number was April.

Special Winds—The Chinook

In some instances local peculiarities of the wind have prevailed through a wide enough region and with enough distinction to give the winds in which they appear a special name. In eastern Montana and southward into northern Texas very frequent, and in winter often very injurious, are what are known as "northers." They are simply the winds that always blow into the rear of a cyclone, but showing here

more severity and more of northerly and less of westerly direction than in other regions. It is winds of the same class, but extraordinarily strong and laden with fine, prickly snow, that constitute the blizzard, which attains its greatest severity in North Dakota.

The most curious and truly original of the special winds is the "chinook." We expect air brought down from the tops of high mountains to be cool. And we expect this also of air moving in pursuit of a cyclone. The chinook is a wind that works the miracle of carrying air down from the mountain-tops and into the rear of a cyclone, and at the same time spreading a great warmth through the region it traverses. The eastern slope of the Rocky Mountains in Montana, Wyoming, and Colorado is the main field of its activity. Its method, once a good deal of a mystery, but now quite well understood, is simple enough.

The chinook is nothing more than an extraordinarily swift and sheer tumbling down of a body of air from the mountain heights into openings offered by a body that is flowing off from the lower slopes under the draft of a cyclone at some little distance to the eastward. The lower body is cold. The upper body is, at

its start, cold also. But, like all bodies of descending air, it warms under the force of descent, and as this force, under the conditions then prevailing, is particularly strong, the air, by the time it reaches the lower ground, is much warmer than that of which it takes the place. Moreover, it was to begin with extremely dry, and the warmth it acquires in its rapid fall makes it greedy of moisture. It drinks up all that comes in its way, and so becomes doubly transforming—both warming and drying—to the temperature of the regions over which it spreads.

The changes the chinook effects are sometimes of a suddenness and degree that one can hardly credit. It can occur only when at the places to which it descends the weather is cold. A temperature of anywhere from zero to thirty degrees below will be prevailing. Suddenly a wind starts up from the southwest, and in fifteen minutes the temperature will have leaped to anywhere from ten to forty degrees above zero. Rises of temperature of even more than forty degrees under the chinook's visitations occur; but a rise of forty is about the most that is ever effected by the first onset.

The Higher We Go, the Stronger the Wind

As we are made aware almost any time when we ascend to the housetop or to an open hilltop, the velocity of the wind increases with elevation. The increase is at a more rapid rate down low than high up. This it naturally would be; for in its lower section the ascent is an almost instant stripping away of bulky obstructions, such as buildings and sharp outcroppings of land. Anywhere well above all such obstructions the change of conditions with ascent becomes relatively slight. But the increase, while more rapid, is also, as any one can see that it must be, much less regular below than above. This causes some embarrassment to the weather observers. Their observations of wind direction and velocity, to have any general value, must be made at somewhat of an elevation, and they always are. But there is no real telling what elevation at one and another station will put the several stations on an equality with reference to the irregularities down on the ground. The observers meet the difficulty as best they can by their skill in calculation; and this is quite well enough for most practical purposes.

They would have another embarrassment in the fact that the winds never come in a continuous flow, but always in rises and falls, only that they have subdued the wind into making, with the aid of automatic devices, its own record. All through the day, all through the night, and all through the year, and whether any observer is present or not, it is tracing on paper, in a plain, infallible line, just as if it were a human draftsman, its every descent and mount in strength, from none at all to the mightiest it is capable of. Because of this ingenious management of it a thing always invisible and ever varying gets exhibited to us, at chosen places of observation, in its quality and action with such a constancy and minuteness as was never any human being nor, indeed, any living creature.

XII

CLOUDS AND SUNSHINE

IN periods of dark weather it might comfort us to remember that, on the whole, we have sunshine more than half the time—that is, of the time when the sun is present, of the daytime. Seeing how necessary, after all, clouds and their frequent consequence, rain, are to us, this seems a generous amount. But, of course, all parts of the country do not share alike in it. Always, the warmer the air the more moisture it can carry without forming clouds; and the average fairness of a region is, therefore, always according to the proportion prevailing there between the moisture of the air and its warmth.

This proportion has many variations under the successions of day and night, the rotation of the seasons, and the passage of storms. But it is easily reduced to an average, and to that the average of sunshine is bound to correspond. Places where the ordinary moisture is abundant

and the ordinary temperature relatively low are the cloudy places. Those where, on the other hand, the moisture is scant and the temperature relatively high are the fair ones.

The north Atlantic and the north Pacific coasts and the lower shores of the Great Lakes offer just the right conditions for cloudiness. Their latitude gives them a low average temperature, and the neighboring bodies of water give them much moisture. These are, therefore, just the parts of the country that, on the whole, have the least amount of sunshine. In the north Pacific states, taking winter and summer together, there is sunshine for not more than four-tenths of the time (that is, of the daytime); and for winter only the average falls to about three-tenths. The amount is not so small as this along the Lakes or in any of the north Atlantic states. The annual proportions there for the places that have least are from four-tenths to five-tenths.

The part of the country that has most sunshine is that southwest region which, shut off from the Pacific Ocean, the only near body of water, by high mountains, and lying in a warm latitude and also out of the path of general storms, holds the record against all other parts

of the country, and even against a good part of the world, for dryness and heat. It comprises portions of California, Nevada, Arizona, and New Mexico. It has sunshine seven or eight tenths of all the daytime of the year.

Outside of these few and comparatively small regions where the amount of sunshine is either most or least, the distribution of it is strikingly even. In practically all the rest of the country there is sunshine for always something more than five-tenths, but for never much more than six-tenths, of the daytime part of the year. There is rather more in the southern half of the country than in the northern. The air is ordinarily moister through most of the southern half than through most of the northern. But it is also ordinarily warmer, and so much warmer that it is less often forced to gather its burden of moisture up into clouds. And exactly this condition marks the summer in contrast with the winter; and there is everywhere considerably more sunshine in summer than in winter. The ordinary difference shows places that have sunshine, say, six-tenths of the time in July as having it only about five-tenths of the time in January. But there are places

where the difference between summer and winter is three and even four times this.

The Ordinary Midday Cloud

While our allowance of sunshine is, on the whole, generous, there are, except in the dryest parts of the country, comparatively few days that show no clouds. Over the larger part of the country the appearance of a certain kind of cloud is a mark, indeed, of the day's fairness. The sun rises clear; the ground and the air nearest it begin to warm. Then the air, as it warms, begins to rise, and about the middle of the morning there begin to appear, not very high up in the sky, bodies of cloud that look like heaps of snow floating on a smooth and brilliant sea. Such clouds have, as a rule, a well-marked, straight base; and it is this, added to a slow, steady movement on just one plane, that especially gives them the aspect of floating on a surface of smooth water.

All that is necessary to the formation of such clouds is that the lower air shall be fairly moist and that just the ordinary daily warming-up shall be enough to cause it to rise to a height where, cooled, mainly by its own expansion

against the colder air about it, it shall be forced to condense some of the moisture. Condensation begins at the uneven, upper fringes of the ascending stream; and the resulting cloud shows, therefore, either a quite irregular or else a definitely rounded top. As by continuing ascent more of the stream comes into the region of condensation the cloud builds up higher. But the base of the cloud remains on the line where condensation becomes possible. This, obviously, it must do. It could not wait until it got above that line to form; and if it fell below, it would be blotted out. The line need not always be straight. But it tends to be so in the placid, even weather to which clouds of the kind in question are peculiar. Also, it is higher or lower according to the amount of moisture in the ascending column. With a small amount the column will be able to rise to a colder—which means, to a higher—level without condensation than with a large amount.

Because of its heaped-up form this kind of cloud is known as cumulus. Appearing as it does in the middle of the day and in an open, clear sky, it is seen more nearly in its complete form than any other kind, and is of all the easiest to identify. When one has formed, it drifts

away under the general movement of the layer of air in which it has formed. Then, perhaps, at the same place another and, following that, another will form. Or perhaps others have formed at places a little removed, but on the same level. There will then be seen a line of clouds moving peacefully along, like a line of high-laden barges.

The movement is very slow—as a rule, less than a mile an hour. But the voyage is rarely long. The level on which it proceeds is usually not more than a mile above the ground, and easily feels any change of condition offered there, and soon, by its own inequalities or perturbations, makes shipwreck of the fragile craft it is floating. But the number of clouds swimming about a little and then dissolving increases until after the middle of the day. Then they cease to form; one by one those already formed vanish, and by nightfall the sky is clear of them.

While this kind of cloud-making is common over a large part of the country, it is always, in the actual proceeding, a very local as well as transient affair. The amount of it is dependent mainly on the conditions at a given time and place. There is more of it, though, everywhere

in summer than in winter, because the lower air has then more moisture and warms up more under the daily passage of the sun.

Fog

This is cloud formation in its most familiar and simplest exhibition. It is the cooling and condensation of a column or body of air at the top. But we have an even more familiar example of precisely the same transformation in the cooling and condensation of a body of air at the bottom. Relatively warm, moist air in contact with the ground at a time when the latter is cooling rapidly suffers the same effect as if it had risen into a layer of cooler air. The product, in this case, is not known as cloud, but as fog. There is no essential difference between the two, however; and when a bank of fog either is carried up or forms a little above the ground, as often happens, it becomes, by virtue merely of position, cloud of the kind known as stratus—a horizontal sheet or layer. Building, as it does, against the unyielding surface of the ground, it more inevitably becomes a sheet or a succession of close layers than a cloud formed at the top of a column of air pushing up through other air unevenly.

LAYER, OR SHEET, CLOUD (STRATUS)

Both cirrus and cumulus, the two principal kinds of clouds, pass at times from their more distinctive forms—the one feathery, the other heaped-up—into sheets or layers. But clouds often form low down in the sky, especially toward evening, rather directly into sheets or layers. They more or less resemble fog, and often are fog, lifted a little from the ground. There are often rents or separations in the sheets through which the blue of the sky shows with peculiar vividness.

It is largely under the advance of the sun that clouds are formed. For the whole year and the whole country midnight is the part of the day when there is least cloudiness, and from two to three o'clock of the afternoon is that in which there is most. But fog is attendant largely upon the decline of the sun. It forms, not exclusively, but oftenest, at evening or night, as the earth loses the heat acquired during the day; and its tendency is to dissipate as the sun ascends. But there are often conditions, especially in winter, under which it persists through the day. It is, in general, more frequent in winter than in summer. But on the Atlantic and Pacific coasts and the shores of the Great Lakes, the parts of the country in which it is most frequent, there is more of it in summer than in winter. Of the two coasts the Pacific has more of it than the Atlantic has. Of the latter the New England part has most; and of the former the middle California, or San Francisco, part has most.

Evening Clouds

Much of the thickness that so often appears on the horizon at evening is simply smoke or dust. These become more and more an ac-

cumulation in the lower air toward evening, because then, under increasing coolness, the lower air has less and less circulation. What of this thickness is not smoke and dust is faraway fog. But there is apt to be, at evening, on a fair day, somewhat above the horizon, a sheet of cloud of the general stratus type. It may be strict stratus—that is, a strip of lifted fog. Again, it may be a strip of cloud formed just like fog, except that instead of forming directly on the ground it has formed on a layer of air relatively cold, like the ground, from a warmer layer lying on top of it. This condition of a cool or cold layer of air under a warmer one is not unusual down near the ground at the time of the daily cooling-off.

Also favorable to the formation of evening clouds is the afternoon breaking-up, with, perhaps, some settling down and reformation, of the conditions and material that, through the middle of the day, produced the cumulus clouds. Often the midday cumulus clouds themselves, under some pressure above and around them, instead of heaping up in their more ordinary way, spread out horizontally and run together and become a range rather than separated piles, and even smooth out into

a sheet. This might very well mark a warmth in the air above that, as the lower air cooled toward evening, would produce, lower down, layers of evening clouds. The evening clouds are apt to settle lower and lower as the cooling continues and to disappear soon after nightfall.

The Highest Clouds

There are, no doubt, clouds formed so high up in the sky that we cannot at all see them. The highest of all are the cirrus—clouds composed of ice particles; and of them the highest that we do see are so far away and so thin that they do not show as clouds, but only as a peculiar whiteness of the sky. Sometimes the higher ones become visible only as rings, or halos, about the sun or the moon or stars. They are not rings themselves, but thin and often wide-spread veils, and the rings are simply a play of light from the veiled body on particles of the cloud.

In the United States the average level at which cirrus clouds form is about six miles in the summer half of the year and about five in the winter half. The average levels of formation are considerably higher for all classes of clouds in the United States than in Europe;

and for all classes the average velocity is also considerably greater here than there. The average velocity of cirrus clouds here is about four miles an hour in the winter half of the year, but only a little more than half that in the summer half. Thus, while the height is greater in summer than in winter, the speed is less; and this is true not only of cirrus, but of all other classes of clouds.

In both height and velocity the cirrus clouds often immensely exceed their average. At the kind we oftenest see one must look with some closeness to detect that they have any movement. But the higher cirrus have sometimes a speed of anywhere from a hundred to two hundred miles an hour. And while about six miles above sea-level is their ordinary height, they may be as much as ten miles above sea-level. Their formation at such heights gets an added interest from the fact that any kind of condensation of water vapor in the air, whether into fog or cloud or rain, is a collection of the vapor on particles of dust. As dust gets into the air, presumably, only from the earth, the higher clouds are a mark of the great heights to which considerable quantities of it must be carried.

Thin and feathery or fibrous strips or star-rings-out or veils of a light silver hue, and with the look of being high up and cold, are the general forms in which the loftier cirrus cloud exhibits itself. Only when it has either dropped down somewhat from its highest levels or formed on somewhat lower ones does it yield the images of fish-scales and horse-tails by which it is best known. It may then even be not wholly cirrus—not wholly ice-cloud—but partly water-cloud. It sometimes forms in the undulations and contacts of the great overflowing and counterflowing currents of the general circulation of the higher atmosphere. In that case it has no connection with any relatively brief and local warming and cooling at or near the ground. But it arises as well, and in large quantities, from most of the low-down disturbances.

The topmost part of the manifold cloud structure of a thunder-storm is very often quite visibly cirrus, spreading out from the central point of the storm, somewhat backward, but farther forward, or in the direction the storm is traveling. Also there is always, as has been already explained, cirrus at the top of cyclones, spreading from the center of these, as from that

of the thunder-storm, somewhat back, but farther forward, and giving by its forward spread a from one to two days' warning of the cyclone's approach. Cirrus flowing out from and beyond a cyclone is the kind we most frequently see. Its movement is eastward.

Storm-clouds

The cirrus, then, in its more familiar forms is always a storm-cloud. A storm begets it, and its appearance is an announcement either that the storm is coming or has gone by. The great spreads and masses of storm-clouds are, however, cumulus—exactly the same in composition and manner of formation as the bright, serene bodies that are the ordinary creation and token of a fair day. Let the conditions that produce these bodies be, by one cause or another, intensified in some limited locality—the moisture of the lower air increased, and its warming-up and ascension and cooling-off all quickened. Instead of comparatively small, inactive clouds, formed placidly at the top of narrow, slow-rising columns, there will arise extended, rapidly formed volumes, tending to intermingle and to conflict with each other, and so to develop

within them a high energy. By their rapid growth and combination they will occupy more and more of the sky; and if the formation and the incident conflict become intense, there will be high winds and finally rain.

Local aggravations of the ordinary cloud conditions occur with particular ease in summer; and when they are strong what they are apt to become in the end is thunder-storms. Even local aggravations, however, are apt to have their origin in more general ones. The greater cloud formations are always due to cyclones. The vast areas of warm moist air set to moving northward and westward by the draft of a cyclone soon begin to meet with cooler areas, and, partly from contact with these and partly through being forced upward by them, suffer a cooling that produces enormous volumes of clouds.

Here the great scale on which the business is conducted gives the product often a very different aspect from the clear, snowy heaps of ordinary midday condensation. The push and pressure of the great cloud masses, their high interior energy, and the rapid variations—breaks and rises and falls—of the levels of condensation combine to obscure completely out-

lines and movements, and often all we see is a dull spread of clouds over the whole sky, sometimes thin, sometimes thick, but without distinguishable form or character.

Sometimes in a given region the whole affair culminates at just this stage. The cyclone's influence in that region begins to lessen; the spread of clouds slowly dissolves, and so the disturbance ends. But if the disturbance increases, the spread of clouds is apt, without entirely ceasing to be a spread, to thicken up from part to part, with, in these thick parts, great volumes of cloud rolling in and out. At this stage the more projecting portions of the mass often show in their own form and action some resemblance to fair-weather cumulus; and the entire mass is of the same general constitution and character. All the clouds formed or provoked by a cyclone, except the cirrus formed at the top of the cyclone, are essentially cumulus.

It is always from cumulus clouds that rain falls, but from cumulus that, under the special stress and pressure of its formation, has become in its lower part—the part from which the rain falls — somewhat more dense and stratus-like than ordinary cumulus. Because,

though, of the distinction of the rain the rain-cloud has been given a name by itself—that of nimbus. The height of rain-clouds varies from two hundred feet to a mile. The patches and fragments of clouds that are often seen flying wildly just under a rain-cloud have been allowed, even by the weather authorities, to retain their familiar name of "scud."

A spread of clouds tends, in the fore part of the day, by shutting out the sunshine and thus lessening the warming-up in the lower air and on the ground, to make the weather cooler. And it tends, in the latter part of the day, to retard the escape of heat from the lower air and from the ground, and so to make the weather warmer. Under a cover of clouds the lower air becomes sometimes very still, losing much of even its lighter tremors and flutters. If it is not itself murky at such times, we have a condition that is the most favorable of any for seeing distant objects. They can be seen at such a time with a clearness far greater than on any cloudless day. But every day at the times of lull in the ordinary warming and cooling there is apt to be produced in the lower air something of this same condition; and the time from a little before to a little after either sunset

or sunrise is well defined as more favorable than the rest of the day for clear and far seeing.

There has been no end of thought and labor expended in efforts to arrive at a practical and complete classification of the clouds. So far as their general composition and their fundamental method of formation are concerned, the matter was very well worked out long ago. But the circumstances in which they arise and travel and dissolve are of wellnigh infinite variety; and so they are themselves, in their actual appearance and behavior, probably the most variable objects on which the eye of man ever falls. And since man is man, this makes them to him also one of the most fascinating objects on which his eye ever falls. It gives them the enticing, infatuating quality of materialized spirits, while they hold, of course, over these always a clear advantage in the matters of reality and form. Any one who has the habit of glancing at the sky and the clouds is sure of at least one delightful moment whenever he steps out-of-doors. But even any one in whom this habit is only casual is likely to become plagued with a desire to pick out of the limitless variability and dissimilarity of the clouds every possible shred of likeness, constancy, and

order. And this is, in effect, what has been aimed at in the later endeavors to classify them.

In the classification most accepted ten forms are defined; and they are chosen and arranged on the principle of exhibiting the three fundamental kinds of clouds—cirrus, cumulus, and stratus—in their most typical stages of development, combination, and transition. That the primary forms, under the many stresses to which clouds must be constantly subjected, make all sorts of conversions of themselves and of unions with each other, changing from distinct piles or strips or bands into veils and sheets and areas of patches or of tufts and balls, is very clear. But it is still only partially determined how these changes come about and what they severally mean.

The Colors of the Clouds and the Sky

For their varied and brilliant colors the clouds and the sky are much beholden to those foreign substances in the air that are grouped under the name of "dust." The colors are wholly due to some interruption of waves of light by either particles of dust or particles of

the permanent gases of the air. According as the interrupting particles are large or small and turn back or break up or scatter about the light waves in one direction or another, with reference to the observer, one or another color appears. The upper parts of the sky are blue, especially when looked at with one's back to the sun; and this is largely because the upper air is freer from dust than the lower air and the dust there is apt to be of finer grain. In the lower sky, where the dust is both coarser and more abundant, the blue gives place to white. Whether low or high, the sky is more white than blue when we look toward the sun, because especially of the greater directness with which the light then comes to us. The sun itself, because simply of the special make-up of the medium through which we see it, is light orange. If the medium were entirely stripped away and the sun seen with nothing of the atmosphere before it, the best opinion is that it would be blue. The sky, on the other hand, under such a stripping, would, it is thought, be black.

Whenever, from any cause, the air is dustier than ordinary, or when the light travels through a particularly long section of the dustier part,

less of blue and white and more of the strong colors, like yellow and red, appear. It is because simply of the sun's shining through a greater length of lower air at sunset and sunrise than during the rest of the day that at those times the sky shows a special abundance of bright colors. Preceding sunset the colors strengthen as the sun goes down; following sunrise they weaken as the sun rises.

The clouds partake of the general color of the sky, but also modify it more or less according to their own composition. During the middle of the day they are light or white in the parts that get the full light of the sun and gray or blue in the parts that are shaded from it. With the sun in front of them, and so at the back of the observer, they are apt to show bright in the central part and darker at the edges. But when the sun is behind them it is at the edges that they are likeliest to be bright. They appropriate freely of the general strength of color in the evening and the morning sky, and often, like great geniuses who appropriate freely, add so much quality and grace of their own as to get credit for the whole creation.

In general, the high clouds are lighter than the low ones; and the highest, the cirrus, keep

pretty steadily their prevailing hue of light silver. When, though, a veil of cirrus makes a halo about the sun or the moon, the light of the veiled body falls on the ice particles of the cloud in such a way as to produce not only a ring, but often a ring of the brightest colors, red inside and blue outside. In the smaller rings known as coronæ, which also are produced by thin clouds lying over the sun or the moon, the cloud particles are not ice, but water, and when bright colors appear the blue is inside and the red outside. It is in the several kinds of cumulus cloud that the colors are exhibited in their greatest range and brilliancy.

The incalculable variety and splendor of the colors, added to a ceaseless change of form, gives the clouds, even for the most careless eye, an unmatched and limitless magnificence. Moreover, in them all the activities and intentions of the whole system of the weather are bound up as if in immense decorated, gold-clasped books, written half to inform and half to mystify. No wonder, therefore, that we can never really look at them without delight. The only wonder is that of our delight we are so often not conscious: we have it without quite knowing that we have it.

One of the most brilliant of the color spectacles of the sky is not classed as a weather product. This is the northern lights, or aurora borealis. It is an illumination caused by some sort of electric discharge with which weather conditions have not been found to have any necessary relation. That brilliant creation, the rainbow, on the other hand, is produced directly by the weather. It is akin to the halo, and is caused by the light of the sun falling on drops of rain in the air in just the right way to produce an arc of color. Often two rainbows are seen at once. The smaller one, which is also the brighter, is made by light entering the upper portion of the drops. In it the outer edge is red and the inner edge blue. To make the larger and dimmer one, the light enters the lower portion of the drops. In it the inner edge is red and the outer edge blue. Rainbows form sometimes also under the light of the moon.

XIII

DEW AND FROST, RAIN AND SNOW

IT has been calculated that, if the water vapor ordinarily afloat in the atmosphere were precipitated all at once in the form of snow, it would cover the entire earth to a depth of twenty inches. In its transportation and deposits of this invaluable element the atmosphere deals very fairly with the United States. There are, to be sure, a few parts of the country that might complain of neglect, except that, while they get little, they also give little. In its deliveries of moisture the atmosphere but returns to the earth what it has gathered from the earth, and in general it restores to a region, and at times of special need, about in proportion as it has received from that region.

The quality of timeliness in the delivery is a most important one. To this in part, as well as to good quantity, is it due that the United

States as a whole never fail of a sure productive supply. An annual average rainfall—rainfall, in weather records, includes both rain and snow—of not less than twenty inches is sufficient, if seasonably distributed, for agricultural production without irrigation. Some comparatively small parts of the country do not have even that much. But far the greater portion of it has an average annual rainfall of from thirty to fifty inches, or just the quantity best suited to good growth and good living.

Dew and Frost

In the simplest and most frequent form of precipitation, that of dew, the atmosphere not only gives back moisture to the earth, but also refuses to take moisture that the earth is offering it. The air, cooling at night by contact with the ground, deposits its surplus moisture on the grass and leaves and whatever other cold surfaces it touches. But all vegetation, under the law and force of its own circulation, is all the time expelling moisture through its own surfaces. During the heat of the day this moisture mainly evaporates into the contiguous air. At night, however, the air, being

cold, cannot receive it, and it condenses where it lies directly into dew. Dew may come, therefore, as well from the ground as from the air; and from which it shall come most will depend on the conditions of the particular time and place.

All dew-making, indeed, is brief and local. Very slight and limited differences of condition prevent or favor it. An evening or night of clear sky and quiet air are needful to it. A spread of cloud prevents the ground and much motion prevents the air from cooling to the dew-point; and there must be, either from the air or from the ground, enough moisture to condense. On an ordinary dew-making night the dew begins to fall early in the evening; but the heavier part of the fall is in the latter part of the night, a little before sunrise.

Frost is simply dew formed when the temperature is at or below freezing. It attracts more attention and seems a much more important affair because of the harm it does to vegetation. Dew, on its side, does an equal good, no doubt; but the effect is less visible. Then, the frost is always driving us into some activity in order not to suffer by it. With the dew, we have only to sit still and receive its bounties.

Frost, quite as strictly as dew, is a local product. In a region that is generally liable to it, every little bit has its own liability or, maybe, its own immunity. Exposed hilltops have less of either frost or dew than have valleys, and for the curious reason that the air on hilltops tends, as it cools at evening, to fall away under its own increased weight into the lower lands and there make its condensations. Dry regions are, as a rule, just those in which there are especially clear skies and a strong cooling-off at night; and they entirely lack frost or dew only if their dryness is of the extremest type. Either frost or dew, according to the temperature, on every clear, still night is the rule for nearly the whole United States, but with innumerable local variations, according to special exposures and protections.

Since a temperature down at least to freezing is indispensable to the formation of frost, there is a seasonal movement north and south in the general frost area. In North Dakota and Minnesota, that coldest of all corners of the country, killing frosts occur sometimes in August; but usually they begin there about the middle of September. They begin nearly, but not quite, as early in some parts of the

Rocky Mountain and plateau regions. In all the rest of the country they rarely occur before October, and in most of the Southern states rarely before November. For their average time of leaving off in the spring the range is from the middle of March for the more southern states to the middle of May for the more northern, with great irregularity in the western mountain and plateau regions. There are sometimes, though, strong departures from the average. Killing frosts have occurred near the middle of June in localities where ordinarily they are entirely over by the first of May.

The Form and Habits of the Rain

We speak of a "fall" of dew; but, strictly, dew never falls. Even when the moisture of it comes from the air the cold surface on which the condensation occurs is a part either of the earth or of something attached to the earth. But in fog or haze or clouds or rain or snow the condensation is always on cool dust particles afloat in the air. So with any of these an actual fall is, as it is not with dew, possible. It is the fixed habit of rain, simply because in rain the drops are comparatively large and heavy.

RAIN CLOUD, OR NIMBUS

Nimbus is a rather formless mass or sheet of dark clouds from which rain or snow is falling. It is not strictly a kind by itself, but is rather the aspect which clouds of the cumulus or stratus kind take when discharging continuously either rain or snow.

Impossible as at first glance the achievement might seem, raindrops have been subdued to definite measurement. Very small ones are less than three-hundredths of an inch in diameter. Very large ones may be as much as three-tenths of an inch. Those that occur with most frequency range from four-hundredths to thirteen-hundredths of an inch. They fall the faster in proportion as they are larger. Large drops are formed partly, if not wholly, by the coalescing of small ones; and they tend, as they fall, to break up again into small ones. The drops are not hollow but are coats of water enveloping a particle, or particles, of dust. Falling from such heights as they do, only the resistance of the air keeps them from acquiring a force that otherwise would be destructive. Without this resistance a raindrop from a height of only half a mile would become, it has been said, "as dangerous as a bullet." From just how high up any one drop ever comes there is no telling. Often the clouds from which rain is falling are only a few hundred feet above the ground. They are about a mile above it at their highest.

The rain, in its fall, washes the air as thoroughly as it washes the ground. A special

clearness is apt to mark the air just after a strong rain; and it is due not simply to the air's lessened moisture, but to its having been washed free of dust. Curious things are sometimes brought down in the course of such a cleansing: things caught up from the earth and which it would seem that the air could not possibly have retained for the time or in the quantity that it clearly has. Often they are identified as originating in regions far removed from that in which they fall. Occasionally, through having a marked color and falling with great profusion, they make a coat on the ground, and so give rise to stories of red or some other whimsical kind of rain.

The formation of rain is, in general, little more than the formation of an ordinary cumulus cloud carried to a point where the store of water in the cloud becomes so great that some of it has to fall. A body of warm, moist air, underrun and pushed upon by a body of dense, dry air becomes so cooled under the mere force of its struggle to rise and spread out that it must expel or condense some of its moisture. Even as cloud the condensed moisture is heavier than the air, but so little so that a very slight upward pressure of the air will suffice to keep

the cloud afloat. But the instant it exceeds the normal weight of cloud, unless the upward movement or pressure of the air becomes in some way equally abnormal, a fall of some portion of the moisture is inevitable.

Occasionally the condensation is so rapid and intense that rain is formed directly: there is no cloud, and the rain falls from a perfectly clear sky. And occasionally, when the lower air is very warm, rain formed above evaporates before it reaches the ground, and it can then be seen directly overhead and no drop of it be felt. Arizona is a region that sometimes exhibits this phenomenon with extraordinary clearness. With us very much the largest part of the rain is a condensation from bodies of warm, moist air thrown into disturbance by the force of cyclones. The larger number even of what appear as simply local rains are due to cyclonic influence.

So much of an inch, or so many inches of rain means simply that rain to that depth has collected in a measure held out for it during a given time. The presumption is fair that the rain fallen to the ground is in close to the same proportion. A hundredth of an inch in an hour is about the lightest fall that occurs. One inch

in an hour is violent. But in hard thunderstorms, and especially in those that produce cloud-bursts, we sometimes experience falls many times greater than that. There is record of a fall of eighteen inches in an hour. The greater of the sharp falls are produced only in very dry times or in very dry localities. A fall of half an inch in a day is heavy; but falls of an inch in a day are rather frequent. The average fall on a single day is only two-hundredths of an inch.

There is, undoubtedly, for most localities a rainy time of day. It has not much value, though, because one can never be quite sure what it is. It changes more or less from season to season and from place to place, and even in a given place and a given season it has its variations. At most places in the United States less rain is to be expected during the warming-up part of the day—say, from five o'clock in the morning until two in the afternoon—than in the rest of it. But as between afternoon and night the division is apt to be dim. In the greater storms rain is likely in any part of the day. In even the rainiest of such storms much the greater part of the rainfall occurs, however, within the limits of a single day—or within,

that is to say, a period of twenty-four hours. The highest average of continuous rainfall in any parts of the country is six hours. This is along the Atlantic, Pacific, and Gulf coasts.

Over nearly the whole country there is some amount of rain or snow on about one-third of the days of the year, and none on about two-thirds of the days of the year. The only important departures from this average occur in parts of California and of the Rocky Mountain and plateau regions, where the average number of days in the year that produce any rainfall is considerably less than a hundred. The rainy days, naturally, are considerably fewer everywhere than the cloudy days.

Distribution of the Rain over the Country

Naturally, there is much more evaporation from the great bodies of water during the warm half of the year than during the cold half. The air has in it over most of the country several times more moisture in midsummer than in midwinter; and thus in most parts to rain proves rather easier in summer than in winter. Only along the Pacific coast and in the northern part of the region between the Sierra Nevada

and the Rocky mountains is the winter half of the year the rainier half. In both of these sections the air that bears moisture comes mainly from the Pacific Ocean. In summer it is warmed by contact with the land; in winter it is cooled. In winter, therefore, it most parts with its moisture. Just along the Pacific practically no rain falls except in the winter half of the year. It begins lightly in October, comes to its greatest in December, and then, diminishing gradually, finishes in April. It amounts to enough to make, in the northern half of the Pacific coast region, an annual fall of from eighty to somewhat over a hundred inches, much the largest annual fall in any part of the country and one of the largest in all the world.

The other of the two sections in which winter rains prevail has a somewhat even distribution through all but just the summer months. Its whole annual fall, however, is small, nowhere more than twenty-five inches and in some parts scarcely more than ten. It comprises the state of Idaho, the eastern parts of Washington and Oregon, and the northern parts of Utah and Nevada.

The southern parts of Utah and Nevada unite with western Arizona and southeastern

California to make the region of least rainfall of any in the country. The record established here in the dryest part must, indeed, at least equal any on the face of the earth. It amounts practically to no rainfall whatever. The more favored parts have an annual fall of eight or nine inches. Most of it occurs high up on the sides of the mountains and is largely in the form of snow.

In eastern Arizona, New Mexico, and western Texas, where the annual fall is from fifteen to twenty inches, about a third of it comes rather evenly divided between the months of July and August. All the other months get some, but May and June the least.

In all the country from the Rocky Mountains to the Mississippi River and north of Texas every month in the year has an appreciable rainfall, but the larger part is in the latter half of spring and the first half of summer. It is especially in this region that the value of the fall lies largely in its timeliness. Through all of the western half of the region the annual fall is scant—from fifteen to twenty-five inches; and if it did not come, as it does, mainly in the planting and growing season many a wide area that is now highly productive would be

barren. Through the other (the eastern) half of the region the rainfall is ample—from twenty-five to thirty inches for the year.

For the country from the Mississippi River eastward the annual fall ranges from thirty to fifty inches; and the twelve months share in it almost equally. The summer months lead, but, as a rule, not largely. There are practically no dry months.

Snow and Its Fall and Distribution

Rain, at its formation, is of a temperature somewhere above freezing. But it is often reduced to a temperature below freezing by being carried through masses of cold air. In such a case it may turn directly into ice and make the rest of its fall and reach the ground as sleet—that is, as grains of ice, and not as drops of water. But, instead, it may reach the ground cold enough to freeze, yet still unfrozen; and then it becomes on whatever cold surfaces it lands, such as those of buildings, streets, or trees, a coat of ice. When, however, at the first formation the vapor condensed is itself of a coldness equal to freezing the product is, not rain, but snow; and between rain and snow

this is the only essential difference. Snow also is sometimes turned into sleet, and because in its fall it is not, like rain, cooled, but warmed.

Snow is always a greater wonder to us than rain, mainly, no doubt, because of its comparative infrequency, but certainly in part because of its bright and varied play as it is coming down. Also because of this last, snow, at its fall, is always enlivening, whereas a fall of rain often is not. Even in large cities, where only a few inches of snow insure several days of obstruction and nastiness, people feel their spirits coming into a certain gaiety the moment a fall begins.

Of its various graces the snow holds what is perhaps the one most curious, not quite open to instant sight. This is the beautiful and manifold forms it takes in its crystallization. Every single flake, if not injured in its fall, shows an orderly, intricate, lovely pattern; and yet all are different. Thousands of them have been accurately photographed and then minutely compared, and never are any two alike. They exhibit, though, enough of rule and resemblance to content somewhat the human propensity to classify things. It has been determined that there are general kinds peculiar some to small

flakes, some to large, and some to flakes falling in one or another of the four quarters of a cyclone.

Made up as the snow is of outspread, feathery bodies, and not of compact pellets, it has a slower fall than the rain. But the fall is more rapid according as the flakes are smaller and harder; and because of a prevailing difference in just this the falls are apt to be more rapid in the middle of winter than at either end of it. The range possible is well marked by, on the one hand, the big soft flakes that, especially in early spring, come gently down, to melt perhaps at their first touch with the ground, and, on the other hand, the driving ice needles that give such painfulness to the midwinter blizzard. Snow has about ten times the bulk of rain, and it is customary in measuring falls to regard ten inches of snow as the equivalent of an inch of rain. In the eastern part of the country the heaviest falls occur, like the heaviest falls of rain, in connection with cyclones from the southwest.

Southern California, just along the coast, and southern Florida are the only parts of the country that never have snow. The greatest falls are in the Sierra Nevada and Cascade

mountains. They amount to from three hundred to four hundred inches in the course of a year. Large falls are usual also in various parts of the Rocky Mountain region—falls of from one hundred to more than two hundred inches a year. East of the Rocky Mountains and across the more northern part of the country the average annual snowfall is fifty inches. Upper Michigan makes an exception by showing in some districts an annual fall of more than a hundred inches. There is a gradual lessening southward. Through the Gulf and south Atlantic states the average for the year is five inches.

Great individual falls occur only in the North. But they occur in the East as well as the West, and one of the greatest of them reached its highest severity in and around New York, where it is kept in eminent memory as "the great March blizzard of 1888." The range of such falls is from eight to thirty-six inches, falling within a period of twenty-four hours. Those of the largest type are much oftener reported than seen. A three-foot snow, a five-inch rain, and an eighty-miles-an-hour wind, while offered to us never but as wonders, still are offered with some frequency, owing to the play of temperament in reporters. Weather

Bureaus put their confidence, therefore, only in instruments.

Hail-storms

In the midst of thunder-storms we often get what is neither rain nor snow, but yet has unmistakable snow embedded in it. This is hail. The hail-stones, which are more or less distorted balls made up of layers of ice and snow, show that they must have been formed where the air was cold and in violent whirl. They vary much in shape and also in size. Just before a fall of hail begins the air below is apt to show an extraordinary closeness. It freshens rapidly as the fall progresses. Coming usually but as part of a thunder-storm, hail-storms come mainly in summer. They are rare in winter, and they are rare also at night. A particularly sultry summer afternoon is the time that seems most to invite them. They are never of wide extent, and they are apt to be repeated in localities that favor them.

Droughts and Floods

Rainfall, like all the other elements of the weather, has its excesses, both of abundance and

deficiency. Those involving single regions or sections are rather frequent. Every year is apt to produce one or more of them. But those extending over a great part of the country are rare, and become historic. Eminent among such is a drought that began in 1893 and did not wholly finish until 1895 and that affected all the country from the Rocky Mountains to the Atlantic Ocean. Yet the total crop production of the country did not fall during those years greatly below the normal. The smaller droughts are often more damaging, within their limits, than the large. They sometimes last with full intensity two or three months. The latter half of spring and the first half of summer, the parts of the year in which for most of the country the rainfall is greatest, are likewise the parts in which droughts are most common and also most harmful. An interesting fact in connection with droughts is that they are apt to be immediately preceded by a particularly heavy fall of rain.

Of floods the greatest ones arise when warm winter storms produce, along with heavy falls of rain, a thawing out of large accumulations of ice and snow. This is a condition that sometimes occurs in the early part of January, at

which time winter has a habit of letting go its hold for a week or two in order only to take a stronger and longer one. The habit is not constant nor well defined; but it has answered to make belief quite general in what is known as the January thaw. An enormous flood is, however, a danger offered much more by February or March than by January, and by the complete than by a partial break-up of winter.

The greatest flood we can possibly have is one that involves, as occasionally one does involve, the entire basin of the Mississippi River, an area of 1,240,050 square miles. The greater Mississippi River floods come usually in just one way. They begin in the lower Mississippi, where all the bordering country is flat and low, under the passage of a series of heavy rainstorms arising in the Southwest. The rainfall may not be much above what is normal for the place and time of year, but it suffices to raise the waters of the lower Mississippi nearly or quite to the danger-line.

The storms, one close after another, travel on from the Mississippi northeastward. They continue to produce heavy falls of rain, and by their warmth they produce also a general

thaw in the snow and ice laden mountainous regions of West Virginia and western Pennsylvania. The result is a great flood in the Ohio River. This is soon added to the one already too well begun in the Mississippi. Under the addition the Mississippi flood not only heightens and widens southward, according to its natural flow, but also backs northward into the upper Mississippi. It may back voluminously enough to spread even into the mouth of the Missouri River. If now, under the break-up of winter in the North and the Northwest, individual floods are added from the Missouri River and the upper Mississippi, the inundation becomes one of inconceivable immensity, and it injures in proportion to its magnitude.

A flood of this description may occupy as much as three months in its building-up and dispersion. At the places most exposed to it the waters may rise to as much as eight or ten feet above the danger-line, and may remain at some such height for as long as a month. And it all comes about in a manner so easy and simple, so without real abnormalities, that we might almost expect it to occur every year instead of, as it does, once, say, in four or five

years. What saves us is that, while all of the conditions for one of these mammoth floods arise in greater or less degree every winter or spring, some chance keeps them from arising with just the continuity or simultaneousness needful to produce one. It is a chance for which we may well be thankful.

The lesser floods occur with much more frequency, and they often do much damage. But all the damage they do, and even all that the great ones do, is not enough to make the people of any part of the country want to give up either their rivers or their rain-storms.

XIV

THUNDER-STORMS AND TORNADOES

THUNDER-STORMS always come suddenly, pass quickly, and are limited each to a comparatively small region. They might seem, therefore, to be a kind of vagary of the weather. When they occur in winter, which is but rarely, they do mark a departure from the ordinary course of things. It is not, however, so in summer. Then they are as definite a part of the regular, the systematic weather as are cyclones and anticyclones. And they have in both winter and summer a close relation to these.

The large amount of heat and moisture in the air in summer keeps it at that season peculiarly well prepared for quick overturnings. The descent of a body of colder air instantly sets things off. The sharpness of the conflict provokes electrical discharges, made apparent in lightning and thunder, and provokes also strong dashes of wind and rain. The amount

of rain produced is, considering the small extent of the storms themselves, notably large. The larger part of the rain of the year comes from cyclones. But the larger part of the rain of the summer half of the year, which is rather the rainier half, comes from thunder-storms.

For their bounty in this the thunder-storms cannot, however, take the entire credit. They themselves are largely the creations of cyclones. They might, indeed, be described as the cyclone's preferred way of producing rain in summer. It is mainly under the atmospheric movements set up by cyclones that the bodies of cold air descend and begin to root out the bodies of hot air with the abruptness that makes thunder-storms. Many occur that have no apparent relation to a cyclone; but they are only of the smallest and briefest kind. For any but the more casual and momentary, the usual order of the business in the country east of the Rocky Mountains is this:

The Spread of a Thunder-storm Epidemic

A cyclone starts across the country by the northern track, the one by which most of the cyclones go in summer. According to the habit

of cyclones following that track, especially in summer, it produces about its center little or only moderate rain. But at some distance from the center the bodies of air moving toward the cyclone raise a condition that results in an outbreak of thunder-storms. Within a limited region there will be a number of them all on the same day. The outbreak may occur anywhere from two hundred to nine hundred miles away from the center of the cyclone. Once begun, the infection spreads eastward in clear correspondence with the eastward progress of the cyclone itself. Sometimes the spread is continuous, but sometimes it is by leaps from region to region, one receiving it full strength and breaking into storms, and another remaining entirely immune and suffering not even showers. The general disturbance ceases in region after region according as the cyclone travels away; and it continues in any one region never more than two or three days.

The outbreaks occur sometimes to the southwest of the center of the cyclone, and, more rarely, to the northwest. In both of these quarters the storms come almost wholly in either the late afternoon or early evening. They are always small and brief, and never

travel far; but those in the northwest are apt to be violent. Much the greater number of outbreaks, however, occur to the southeast of the cyclone center, and the large thunder-storms arise only in this one quarter. Here the storms often come in the morning, but still not as often as in the late afternoon and early evening. From four o'clock of the afternoon until eight o'clock of the evening is the preferred part of the day with all classes of thunder-storms.

All thunder-storms travel. The small ones are able to achieve only quite short distances before they expire, and they keep to no general direction, for they are entirely controlled by the movements of the lower air and the contour of the ground over which they travel. But the large ones extend up into the air some thousands of feet; and they are, on this account, carried forward by the general movement of the upper air, and have usually a course from southwest to northeast. Some rotation in the storm itself, however, causes it in most instances to show in its actual descent upon a given place as coming from the west. The large ones often travel as far as two or three hundred miles. The ordinary rate of travel is

from twenty-five to thirty miles an hour, but occasionally one has a speed of as much as forty miles an hour.

Thunder-storms range in size about as they range in the length of their courses. The small ones may be in breadth less than a mile, and the large ones as much as three hundred miles. The front of the storm bows inward, so that the edges travel somewhat in advance of the center. The small storms are often scattered by the irregularities of the land; but the large ones often cross high mountains without breaking up. Sometimes one is split by a mountain, and, working round it, part on one side and part on another, travels on as two storms. But occasionally in such a case the two parts after passing the mountain come together again.

"Heat" Thunder-storms

The thunder-storms that have no connection with cyclones often occur, like the others, in considerable numbers at about one time, and all within a certain district. While the storms themselves are always small and travel only short distances, the district within which they are grouped may be of considerable extent. It may comprise, say, an entire state. But there

is no succession of districts, no moving on of the thunder-storm condition from district to district, which is so marked in thunder-storms attendant on cyclones. The little storms bursting forth for a scant half-hour here and there are simply the break-up of an extreme sultriness established in a single region. They are known as "heat" thunder-storms, and the name suits well with their character. They occur almost always in the afternoon, at or soon after the culmination of the daily warming-up.

The thunder-storm has a particular interest because we are permitted to see so much of it. Like the cyclone, it sends out a herald in the form of a forerunning sheet, or cover, of cirrus cloud. The fringy front edge appears sometimes as much as two hours, or fifty miles, in advance of the main body of the storm. As the sheet gradually spreads the lower air, which has been, perhaps, extremely close, begins to freshen. In due time there begin to push up from the horizon, usually in the west, ominous dark piles of cumulus clouds of a kind that have come to be known, because of their heavy rounded tops, as "thunder-heads." They may be as much as an hour's journey away when they first appear. When they have advanced about

THUNDER-STORM, OR SHOWER, CLOUDS (CUMULO-NIMBUS)

These clouds, in their main body, are of nearly the same kind as the fair-weather clouds shown in the frontispiece. Because, though, they are formed, not under the ordinary daily warming and cooling, but under storm conditions, they have greater volume and vigor and produce rain, or, it may be, snow. This falls in local showers from the lower part of the cloud. At their bases shower-clouds are ordinarily about three-quarters of a mile from the ground.

half of that distance the thunder is apt to begin. Ten or twelve miles is about the farthest reach of thunder.

As the heavy dark clouds ascend they disclose a level base, with, hanging down from it, a sheet of lighter clouds from which the rain comes. The lightning becomes more frequent and vivid as the storm gets near. The first actual strike of the storm is in the form of violent wind that sets everything flying. Then comes the rain, first in large, scattered drops, then in a dense downpour. The rain and the wind and the lightning all increase together, and then together begin to lessen. The rain is apt to quicken immediately after a particularly sharp stroke of lightning. It usually somewhat outlasts the wind and the more vivid lightning. The thunder comes sounding back even after the storm has gotten entirely by.

The fall of rain in thunder-storms is apt to be great for the size of the storm, and the small storms are apt to have greater falls in proportion to their size than the large ones. There often comes from a single thunder-storm what would amount, for its locality, to a good fall of rain for a month. It is in thunder-storms mainly that those tremendous downpours known

as "cloud-bursts" occur. They are well named, for the spill, besides being enormous, is confined to a small area and is all accomplished in a very short time. They often cause in their one little region a great destruction.

The Lightning in Thunder-storms and Its Fatality

Considerable destruction is wrought also by the winds in thunder-storms. But their most fearful element is the lightning. We always feel this when we are in the presence of a thunder-storm, and at such a time our sense of it is apt to exceed our danger. Divided up among all the people and all the places, the liability to a stroke of lightning becomes very small; quite small enough, in fact, for the poetic application we often make of it to politicians whose expectations exceed their outlook. But it is still enough of a liability to make entire disregard of it utter foolhardiness.

An average of more than three hundred people are killed in the United States in the course of a year by lightning. This is somewhat larger, in proportion to population, than the number of deaths by lightning in most parts of Europe, where also thunder-storms are fre-

quent, though as a rule of less extent and intensity than with us. In two parts of Europe—namely, Prussia and the Austrian Alps—the number is, however, somewhat larger than in the United States. Of the damage done to property by lightning there are no really close or complete estimates. It must amount, though, in the United States for an average year to a loss of several million dollars.

The distribution of damage and fatalities among the different parts of the country corresponds somewhat, but not closely, to that of thunder-storms themselves. All parts occasionally have such storms; but they are extremely rare in California, and are frequent nowhere on the Pacific coast. They are fairly frequent through the Rocky Mountain and plateau regions. But they are more frequent everywhere east of the Rocky Mountains than anywhere in them or west of them, except in New Mexico and Arizona, where the number is somewhat greater than to the north and west. There are about twice as many, though, in the southern half of the country east of the Rocky Mountains as in the northern half; and of all the eastern country the part that has fewest is New England.

The nearer and only dangerous lightning is that which appears as vivid darts and streaks or, with great rarity, as vivid balls. The sheet, or "heat," lightning is not the direct flash, but a diffused reflection produced by clouds. It appears only at some distance, and often at so great a distance that no thunder is heard after it.

The Weather Bureau has sought to ascertain if different soils have a different liability to lightning strokes, and the information thus far gathered indicates that they have. The liability is, apparently, somewhat greater for loamy soil than for sandy soil, and considerably greater for either of these than for clay soil. Everyday experience long ago discovered a difference in this particular among trees, and the discovery is confirmed by recent scientific inquiry. The safest tree to fly to in a thunder-storm is, unquestionably, the beech; and by far the most dangerous is the oak.

Another thing recent scientific inquiry has done is to restore to the lightning-rod something of the trust which it once so fully held and then later entirely lost. The best opinion now is that a lightning-rod is a real protection if you are careful to have a good one, but that good

ones are not to be had without care. The rehabilitation extends, therefore, only to the lightning-rod itself, not to the old-time lightning-rod peddler.

The Tornado

In clean, concentrated violence no other storm matches the tornado. The West Indian hurricane, even modified as it is apt to be when it reaches us, proves sometimes a mammoth destroyer, and it ranks properly as our severest kind of storm. But its immense harmfulness is due to the fact that it has a wide reach and long endurance as well as high intensity. The tornado, on the contrary, is always small and brief. A few hundred yards is its usual width; its greatest is only from one to two miles. Its very longest journey does not exceed two hundred miles. Often it travels only a mile or two, and usually but twenty-five or thirty miles. And as it has a speed of from twenty-five to forty-five miles an hour, its force is apt to be felt at any one place for less than a minute. But so tremendous is this force that anything the tornado touches is torn instantly to pieces. No other type of storm is so generally destructive and fatal.

Tornadoes may occur in any part of the country and at any season; but they are most frequent in the states bordering on either the Mississippi River or the Gulf of Mexico, and they come oftenest in the spring and early summer. They usually arise, like the greater number of thunder-storms, in the southeast skirts of a cyclone, several hundred miles from the center. They are often themselves called cyclones, and they have this much of the cyclone's character, that they are bodies of air in a regular whirl from right to left. The whirl is rapid, and this adds to their destructiveness. They liken themselves to thunder-storms again by coming sometimes in clusters, and also by adhering in their progress to the general direction of the cyclones on which they are attendant from southwest to northeast. They occur in the afternoon or evening, and always under some condition of extreme sultriness.

Just how tornadoes are provoked has not been fully determined. This much, however, seems to be certain: that large bodies of air, pressing forward from different quarters toward the center of a cyclone, run up against each other and fall into a profound tangle, and that this embroilment organizes the tornado. The

organization is extraordinarily compact and well defined. At a little distance the whole thing is easily seen. It shows as a funnel-shaped trail of dark, whirling, fearful-looking cloud hanging straight down from a body of the same frightful aspect. Its small lower end, now drawn up and now darted down, intermittingly licks the ground. The storm advances with a terrific rumble or roar. Always a few minutes ahead of it there is a dash of rain; and in the midst of it there is apt to be extraordinary lightning and a heavy fall of extremely large hail. Because of its curious ascents and descents it will in one locality do harm only some feet above the ground and in another blast the whole face of it.

Three or four a year is estimated to be the average number of injurious tornadoes in the United States, and a million dollars' worth the average annual destruction of property by them. But the harmfulness of them depends greatly on the populousness and development of the region over which they sweep. When one descended upon the city and environs of St. Louis some years ago it destroyed within half an hour about thirteen million dollars' worth of property and three hundred and six

lives. Yet it was not in itself a tornado of the greatest severity.

In any harmful tornado to loss of property is usually joined some loss of life. In thirteen, occurring within a period of twenty-one years, the lives lost amounted to twelve hundred and thirty-five. The smallest number lost in any one of them was forty-six; and in every one except four the number lost exceeded seventy. One of these tornadoes occurred in Georgia. All the others occurred in the Mississippi valley; two of them in a single state, Missouri, and three in a single state, Iowa.

The Great Tornadoes and Floods of 1913

Just as these pages were going to press there occurred a series of tornadoes that caused a greater loss of human life than ever resulted before at any one time from tornadoes in the United States. And in immediate connection with them came a series of floods which seem at this writing likely to prove also one of the most fatal disasters of their kind that the country has ever experienced.

On the night of Thursday, March 20, 1913, a general storm, or cyclone, central over Lake

Michigan, provoked tornadoes to the south and southeast of it, from which loss of life resulted in seven or eight different states. Much the severest loss was in the state of Alabama, where the number of people killed was one hundred and three. Fatalities in neighboring states brought the total number up at least to one hundred and forty.

The cyclone itself produced through the whole of its general course only light rains; and it showed in no way as being in itself of unusual force until it crossed Lake Michigan. From there on until it reached the St. Lawrence valley it exhibited in the winds directly attendant upon it a record-breaking intensity. Winds blowing at the rate of eighty-eight miles an hour were recorded at Detroit, Michigan, and at Buffalo, New York.

At evening on Sunday, March 23d, three days after the first outbreak of tornadoes, came a second, which was yet more destructive. Of this the greatest severity was felt at Omaha, Nebraska. It is estimated that in that city and its neighborhood not fewer than two hundred people were killed. Next to Omaha, the place that suffered most was Terre Haute, Indiana, where twenty were killed. There

were fatalities also at a number of other places, and the whole number of lives lost in the second set of tornadoes was probably not less than three hundred. This, added to those lost in the first set, makes a total of not less than four hundred and forty.

Previous to this, the highest record of loss of life in tornadoes in the United States was four hundred and sixteen lives lost in tornadoes occurring in groups of different dates, but all in the one month of May, 1896. It was as one in this succession that the great St. Louis tornado came, and the lives lost in it alone numbered three hundred and six. The Omaha tornado would, therefore, seem to have been in itself not as bad as the St. Louis tornado. But the series to which it belonged shows as considerably severer than any preceding series.

The cyclone, or general storm, which provoked the Omaha and other tornadoes on March 23d did not, like the one that produced those of March 20th, develop extraordinary velocity in its own immediate winds. But it did produce along its path extraordinary falls of rain, especially in Indiana and Ohio. The streams in those two states were already running fairly full because of abundant, though not

exceptional, rains from a number of preceding storms. The sudden addition to their waters from this one of the 23d brought them all to flood.

The floods grew rapidly the next day—Monday, the 24th—under the advance of yet another general storm, a narrow, slow-moving trough reaching from Texas northeastward to Lake Erie, and producing torrents of rain in just the localities where more was surest to prove disastrous. The dawn of Tuesday, March 25th, disclosed to the world that Ohio and Indiana were under an inundation of an extent and severity such as not those localities certainly, and perhaps none in the whole country, had ever before experienced. The calamity is at present lying on the afflicted communities so deep that there is as yet no possibility of measuring it. But the loss of life and property resulting from it cannot fail to be enormous.

Since the country most subject to tornadoes grows all the time more populous, the fear is sometimes expressed that their fatality may greatly increase. There is some solace to this fear, perhaps, in the fact that Prof. Cleveland Abbe has ascertained by careful calculations

that "even in the so-called tornado states" the probability that any one of a hundred areas of one square mile each will be struck by a tornado is "less than one-fourth of one per cent. per century." The reassurance of this would, of course, be greater if there were any telling beforehand just which area was to get the scarcely ever to be expected stroke.

XV

WEATHER SIGNS AND SUPERSTITIONS

THE Weather Bureau has its severities, like the weather itself, and one of them is the coldness with which it looks upon the prophets who tell us what the weather will be for a month or a season or even for a whole year. Many of us find these prophets very companionable, though we may not give them our entire trust. If they were suppressed, as sometimes the more scientific predictors seem to think they should be, the household almanac would become a sad compilation, for its jokes are much less enlivening than its weather predictions.

The Moon and the Weather

The "long-range" forecasters all make much of the planets. This helps to put us in awe of them, but is not what most attaches us to them. The planets are so far off and show so

small that we do not of ourselves have, under the sight of them, a constant sense that they must exert an influence on the earth. We do have this sense, however, in regard to the moon; and where the "long-range" forecasters really engage us is in upholding with their own our lingering faith in the moon as a weather-breeder. And in this faith even the true meteorologists give us at least a negative support. They do not contend that the moon has no influence on the weather; they insist only that of such influence no clear evidence yet appears.

There is, of course, no disputing the fact that at what we call the changes of the moon no greater change occurs than at other times; that the changes of the moon are even and continuous, and consist simply in its beginning as a new moon and increasing night by night up to fullness, and then as steadily night by night waning until it passes from sight. And this does impair the validity of some of the time-honored moon maxims. But many of these maxims still enjoy a wide affection and even a wide belief, as, for example, the following:

There will be fair days and fair nights for

three days before full moon and for four days after full moon.

When the moon comes in at midnight, or within thirty minutes before midnight, the weather will be for a month following invariably fine.

A promise akin to this, but for a shorter period, is: Within the limits of ten o'clock and two o'clock at night, the nearer midnight the moon changes any of its quarters the fairer the weather will be during the next seven days. And within the limits of ten o'clock and two o'clock of the daytime, the nearer midday it changes the worse the weather will be during the next seven days.

If the new moon lies on its back, and so will hold water, it will be a dry moon. Little rain will fall while it lasts. But if it lie tipped forward so that the water must spill, it will be a wet moon. It is only another expression for the same adjustment that makes the dry new moon one on which the hunter might hang his powder-horn without risk of its either slipping off or getting wet.

It is largely the charm of the idea that makes us still cherish such maxims; and this, no doubt, has also much to do with our holding

on to the fancy that birds and plants and animals enjoy a greater prescience in the weather than we do ourselves. And perhaps this is true; nobody positively knows. At any rate, we find it pleasing to think, for example, that squirrels and their kind lay up in autumn a greater or less store of food; that fur-bearing animals thicken or thin their coats, and birds their plumage, and trees their moss and bark, and nuts their shells, and vegetables their husks and rinds; and that birds make their migrations, and hibernating animals seek or leave their dens, all in a sure foreknowledge of the mildness or severity of the coming season. There is attraction even in signs that have less plausibility than these, as that: If the rabbit sits up particularly straight, or if the wasps build their nests loose on the ground, or if the apples fall from the trees in quantities rather than a few at a time, the winter will be mild; and if the leaves hang to the trees late in autumn there will be much snow.

But perhaps the most precious to us of all the traditions regarding weather foresight in the animals is that of the ground-hog, or woodchuck, and his behavior on the second of February, or Candlemas Day:

> If Candlemas Day be bright and clear,
> We'll have two winters in the year.

It is just the kind of dinning couplet that, once received into the memory, nothing but death can remove; and, generation after generation, we have all gotten it, never the rest of our lives to get rid of it. With the larger number of Americans it probably embodies their entire knowledge of Candlemas Day; but this little they hold good and tight. Generations may yet come that will not know the couplet; that may, perhaps, be too feeble in mere verbal memory, which is now much deprecated, to acquire it. Yet even they, limited creatures though they may be, will have, one must believe, still some joy in the ground-hog. The second of February will not pass without their demanding gleefully of one another whether the ground-hog came out of his hole; whether, if he did come out, he got to see his shadow, and whether, having seen it, he went back to remain housed until the second winter, which he knew must come, had certainly passed.

Ever to remain dear to us is also the maxim —not, though, an animal maxim except by the grace of metaphor—that if March comes in

like a lamb it will go out like a lion, and if it comes in like a lion it will go out like a lamb.

Men and Things as Barometers

However great or small the gift of animals, birds or plants, or even men, in foretelling the weather for long periods, they all have in their own feeling some good, true, practical premonitions of it for a day or two. To changes in the air that envelops them they are all more or less sensitive, and they betray this sensitiveness in their aspect and actions. For ourselves, sometimes an hour or two, and sometimes two or three days, in advance of a storm we begin to remark that the air is growing close and heavy. It is, in fact, growing open and light; it is lessening in weight, or pressure. The clear, cool air, the air under which we feel lively, is the heavy air, the air of high pressure. But because warm, moist air tends both to overheat the body and at the same time to repress it in its readiest means of relieving itself of excessive heat, that of evaporation from the surface, we often find such air sorely oppressive.

The weather is marked to us only occasionally in this clear way. But we are at all times

as responsive to variations in the quality of the air as the barometer itself. Men, it has been observed, eat better, sleep better, and work better when the barometer is high than when it is low. When the barometer falls we grow limp in body and endurance, and become particularly conscious of all of our chronic ailments and weaknesses.

Since all things animate as well as inanimate have somewhat of the same sensibility, the face of the earth is, we might say, one continuous spread and thicket of weather signs. And the reading of these signs, often a shrewd, often a crude reading, has produced an endless store of homely weather maxims. Because of increasing humidity, smoke falls to the ground, noises become loud, windows and doors cling to their frames, leaves of plants freshen, leaves of books stick together, odors grow stronger, stones sweat, fiddle-strings lengthen, and no end of similar things occur in advance of rain; and their opposites follow it. Further, in token of the rain's coming swallows certainly fly low, and, not so certainly, perhaps, cats carry their tails up and rub their ears, sheep lie about in the pasture and refuse to nibble, hogs grow restless and grunt, roosters flap their wings,

hens nestle and flutter in the dust, and bees stay close in their hives.

Clearly, it is a body of wisdom of unequal value. Many of the maxims comprised in it are true, many are partly true, and many are not true at all. The barometer itself is in the end the only exact barometer.

The Barometer Signs

Because the weather is so largely the product of the long, orderly movements of cyclones and anticyclones the general behavior of the barometer is rather simple. It shows, as a rule, great changefulness only at or near the center of storms. When an anticyclone, a fair-weather area, is in full control of a region the barometer will stand at something above thirty inches, say 30.10 or 30.20. It will stay in about this position some days if the anticyclone is not a hastening one. But as the anticyclone begins definitely to move away there will begin in the barometer a gradual fall.

If following the anticyclone there should be, as there usually is, a cyclone, or stormy area, the barometer will continue to fall and at a steadily quickening rate. As soon as the center

of the cyclone passes the fall will cease and there will begin a rapid, steady rise. But for places at or near the center there is likely to be, as the center passes, first a brief rise and then a brief fall before the final steady rise sets in.

If now another anticyclone is coming forward the rise of the barometer will continue, though at a steadily lessening rate, until the center of the anticyclone arrives and the fair-weather mark of 30.10 or 30.20 is again reached. But if, as sometimes happens, instead of an anticyclone another cyclone follows, the barometer will stop in its rise somewhere short of the fair-weather mark and begin a new fall, and there will be repeated for the second cyclone exactly the movements that occurred before and after the first.

The barometer behaves in a local storm about as it behaves in a general one. For several hours in advance of a thunder-storm, for example, it maintains a steady fall. But it suddenly rises a few points at about the first outburst of the stronger storm-winds. There it pauses somewhat, then again falls a little, and then with the first lessening of the storm begins a continuous rise.

This, then, is the barometer's general habit: It stands at about 30.10 or 30.20 inches during established fair weather. It maintains a steady fall when the weather is changing from fair to stormy, and a steady rise when the weather is changing back again to fair.

As the barometer falls in advance of a storm the temperature generally rises. After the storm has begun, or about the time it ends, the barometer begins to rise and the temperature to fall. But sometimes the temperature remains high when the barometer is rising. In that case there is likely soon to be another storm. We get especially clear illustrations of this in thunder-storms, which so often come one close after another.

The more rapid the changes of the barometer in any circumstances, the more quickly and strongly will follow the changes of weather which it foretells. A gradual fall during a number of fair days indicates not only a change, but a change embracing a number of wet days. A continuous rising in wet weather indicates, on the other hand, that after a day or two there will be a number of days of fair weather. Often, especially in the general storms, a region lying at some distance from the storm center feels

the storm without just getting it. In such a case there may be a considerable fall of the barometer without marked change in the weather.

When the Rain Begins

It is interesting and also useful to know at what marking of the barometer the rain or snow from a coming storm is likely to begin. One of the many valuable bulletins issued for general information by the Weather Bureau gives, in substance, this instruction:

In storms from the southwest or south—storms that are usually indicated by winds blowing from points between east and north—the fall of rain or snow begins with the beginning of the fall of the barometer. In storms from the west and northwest there is at most places a fall of the barometer to as low as 29.90 or 29.80 inches before the rain or snow begins. But along the south Atlantic and Gulf coasts the fall of rain or snow in both classes of storms begins as, or nearly as, the fall of the barometer begins. In winter this is the rule also around the Great Lakes and through the region between the Rocky Mountains and the Mississippi River. In summer,

though, these regions have the rule of most of the other parts of the country, and in west and northwest storms rainfall begins only after the barometer has gotten low.

The Wind as a Warning of the Weather

For the greater changes in the quality of the air we hardly need to read the barometer. We can learn of them simply by our own feeling. In the same way and by looking about a little we can learn fairly well the movement of the wind, which is also a matter of importance in forecasting the weather. At the rear of an anticyclone, or fair-weather area, and in front of a cyclone, or stormy area, the winds are prevailingly from the east. In advance of an anticyclone and at the rear of a cyclone they are prevailingly from the west. But within the two general divisions of east and west the direction varies from point to point north or south according to the region and the momentary state of the weather. The following general rules in regard to the matter all have the indorsement of the Weather Bureau:

Northeast winds indicate rain or snow, and they often indicate "the severest storms to

which a great part of the United States is subject."

Southeast winds are rain-winds, but indicate storms less violent than are indicated by northeast winds.

Northwest winds indicate general clearing and fair weather, and they are usually cool or cold.

Southwest winds also indicate fair weather, and they are usually warm.

Over a great part of the United States a steady and strong south-to-east wind will bring rain within thirty-six hours.

Soon after the wind in a storm shifts from an eastern quarter to a western quarter the weather will begin to clear.

The final shift of the wind into the west or the northwest, under which we get colder weather, is apt to be a sudden shift. Colder weather, therefore, comes as a rule suddenly; but warmer weather comes gradually.

Cloud Signs

Clear and often early warning of changes of the weather is given by the clouds. The high, silvery cirrus clouds appear in advance of the central part of a cyclone, or general storm, any-

where from eighteen hours to two days. They appear also in advance of a local storm, but never more than a few hours. They show at first as strands or wisps or feathery strips or patches. They gradually thicken into a cloak or cast covering most of the sky.

The cirrus clouds make the "mackerel scales and mare's tails" that time out of mind have prompted "lofty ships to carry low sails" in expectation of a storm. Their movement is eastward and almost always from some point between northwest and southwest. The higher they are in the sky the slower the approach, but also the greater the extent of the storm movement they foretell.

But cirrus clouds are not always a warning of storm; for they trail out also somewhat backward from the larger storms, and they often form high up in the sky quite above the lower storm region. Then, when they forerun a storm, they sometimes extend farther than the rain or snow from the storm will reach. Especially after a long period of dry weather are cirrus clouds no sure promise of rain.

But then all signs of rain fail in dry weather. The familiar maxim is perfectly true: the signs do appear, and yet the rain does not come.

Storms do not wholly cease in dry weather; but they are apt to be weak, and in addition they cannot in their travels find moisture enough in the atmosphere to make a rain. They can only start a southerly wind and raise clouds and our hopes of rain.

In regard to cloud warnings of the weather, some of the best approved instructions are:

If streaks of cirrus point upward, the clouds are falling and rain is indicated; if they point downward, the clouds are rising and dry weather is indicated.

If cirrus clouds dissolve and appear to vanish it is an indication of fine weather.

Clouds flying against the wind indicate rain; but a clear sky before the wind is a promise that the rain will soon end and the weather clear.

If clouds at the same height drive up with the wind and gradually become thinner and descend, it is a promise of fair weather.

When on a clear day "isolated clouds drive over the zenith from the rain-wind side [this at most places would be from some point between northeast and south] rain or snow will follow within twenty-four hours—more likely within a few hours."

When a heavy cloud comes up in the south-

west and seems to settle back again look out for a storm.

"Well-defined cumulus clouds [the clouds that come in heaps] forming a few hours after sunrise, increasing toward the middle of the day and decreasing toward evening, are indicative of settled weather; if, instead of subsiding in the evening and leaving the sky clear, they keep increasing, they are indicative of wet weather."

"Clouds upon hills, if rising, do not bring rain; if falling, rain follows."

"Enough blue sky in the northwest to make the Scotchman a jacket is a token of clear weather."

"When the sun in the morning is breaking through the clouds and is scorching, a thunderstorm follows in the afternoon."

Soft-looking, dimly defined, delicately tinted clouds indicate fair weather. Clouds of hard, defined outline and of strong color, especially black or black with a cast of green, indicate rain with probably high wind.

Fog, which is only near-by cloud, is oftener than not the product of established dry weather, and a morning fog is a sure sign of a day without rain. In like manner heavy dew or heavy

frost at night gives promise of a fair day to follow, because dew and frost come only in fair weather.

The Weather and the Colors of the Sky

Ordinary observation has gathered a great number of weather signs from simply the ever-varying colors of the sky. Among the more familiar and reliable ones are:

A bright-blue sky is the sky of fine weather. A bright-yellow sky at sunset promises wind; a pale-yellow sky rain, and a "sickly, greenish" sky both wind and rain. A rosy sky at sunset promises fair weather. But a dark-red sky at sunset promises rain. A red sky in the morning promises wind or rain. "A red sun has water in his eye."

"If the sun sets in dark, heavy clouds, expect rain the next day." Even a gray sunset indicates rain. But a gray morning indicates a fine day.

"When the sun draws water rain follows soon."

And, finally, what in this connection it would be perhaps the most reproachful of all possible omissions not to mention:

Rainbow at night,
Sailor's delight;
Rainbow in the morning,
Sailor's warning.

Conclusion

The weather signs and maxims make as a whole such a volume and are many of them so quaint and impossible that we have come to regard them as somewhat of a jest. But many of them have true value and, with more attention to them, could be made of much greater service in our every-day life and affairs than they are. Even people who are under no practical need to attend much to the weather would do well to have some store of them, and especially of the quainter ones, in ready memory. The recall of them and the matching them with and against the weather itself so helps to make it interesting and pleasant. And to have it interesting and pleasant is, since we must all the time live in its embraces, the most comprehensive of all domestic felicities. It is as a friendly provocation and encouragement to this good relation that these pages have been written by one whose claim on his subject is, it may be confessed, less that of mastery than of fondness.

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THE END

Goodspeed 1930